CLIMATE CHANGE IMPACTS AND ADAPTATION STRATEGIES IN PADDY PRODUCTION

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Climate Change Impacts and Adaptation Strategies in Paddy Production"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Climate Change Impacts and Adaptation Strategies in Paddy Production"** is a bonafide record of research work done by Ms. Susha P.S. under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Chapter I

Introduction

Climate change is perhaps the biggest challenge facing the world today, and the very existence of man depends on how effectively this challenge is tackled. There is global cooperation to device means to cope with this phenomenon, which threatens to play havoc with the lives of people across the globe.

Intergovernmental Panel on Climate Change (IPCC) as early as in 1997, has defined climate change as the statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or due to persistent anthropogenic changes in the composition of the atmosphere or in land use. United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is in addition to natural climate variability observed over comparable time periods. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. Climate change includes gradually increasing average temperature as wells as increased frequency and the magnitude of extreme weather events (Mirza *et al.,* 2003).

Intergovernmental Panel on Climate Change, in its Fourth Assessment Report, reported that the climate change is projected to impinge on the sustainable development of most developing countries of Asia, as it compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation, and economic development. High population in these countries are depending on agriculture for their livelihood, and the financial resources to mitigate the effects of climate change in these countries are scarce. Taken together the influence of rapid population growth and urbanisation, the risk of hunger is projected to remain very high in several developing countries. In the first comprehensive analysis on the economic dimensions of climate change impacts on various spheres of life world over, Stern (2006) estimated the overall costs to be a minimum of 5% of global GDP each year. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of

GDP or more. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.

Agriculture is highly sensitive to climate variability and weather extremes, such as droughts, floods, and severe storms. Studies on climate change report rainfed agriculture as more vulnerable in view of its high dependency on monsoon and the likelihood of increased extreme weather events due to aberrant behavior of South West monsoon. Aberrations in South West monsoon which include delayed onset of monsoon, long dry spells and early withdrawals, all of which affect the crops, and strongly influence the productivity levels (Lal,2001). These aberrations are likely to increase further in future.

There are already evidences of negative impacts on the yield of wheat and paddy, in parts of India due to increased temperature, increasing water stress and reduced number of rainy days. Mall *et al.* (2006), have identified Western Rajastan, Southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Northern Andhra Pradesh and Southern Bihar as more vulnerable regions in terms of extreme weather events. Kumar and Tholkappian (2006) reported that, a rise in temperature of about 1.5^0 C and a rise in rainfall of about 2 mm could result in a decline of rice yield by 3-15 per cent. Also every 1^0C rise in temperature could result in 10 per cent increase in irrigation requirement in arid and semi arid regions. Majumdar (2008), projected a significant decrease in cereal production by the end of this century, in India. The risks of crop failure and poor yields influence farmers's decision on investing on new technologies and level of input us and thus have long term multiplier effect on the general economy (Pandey *et al.* ,2000) . Thus, the impact of climate change on agricultural output is both direct and indirect.

In Kerala, the study conducted by Saseendran *et al.*,(2000), made projection on the effect of changes in weather variables on paddy output. Paddy maturity period is projected to shorten by eight per cent and yield increase by 12 per cent when temperature elevations only are taken into consideration. This showed that the increase in yield due to fertilisation effect of elevated CO_2 and increased rainfall over the state as projected in the climate change scenario, nearly, makes up for the negative impact on paddy yield due to temperature rise. It was also reported that increase in CO_2 concentration leads to yield increase, due to its fertilisation effect and enhanced the water use efficiency. The temperature sensitivity experiments have shown that for a positive change in temperature up to 5 and17^0C, there is a continuous decline in the yield. For every one degree increment, the decline in yield is about six per cent. In another experiment conducted by the same authors, it was observed that the physiological effect of ambient CO_2 at 425 ppm concentration compensated for the yield losses due to increase in temperature up to 2 and17^{0}C. Rainfall sensitivity experiments have shown that increase in paddy yield due to increase in rainfall above the observed values were near exponential. But decrease in rainfall results in yield loss at a constant rate of about eight per cent per 2 mm/day, up to about 16 mm/day. These estimates are made based on crop simulations models, which generally do not account for field level practices and adaptation strategies of farmer operators. The farm level practices and farmer behaviorunder varying climate change scenarios do influence the performance of the crop and resultant farm income. Present study was undertaken with the following objectives:-

1. To quantify and value the impact of climate change on paddy production
2. To assess the public cost of mitigation strategies of weather extremes
3. To understand the farmer's level of understanding and adaptive mechanisms to climate change.

Scope of the study

This is a pioneering study to assess the economic impact of climate change on paddy production in Kerala, based on panel data, drawn from farmer's field diary. The study also tries to assess the extent of damage caused by weather extremes. The farmers level of perception on the concept of climate change and the farm level adaptive behavior also is tried. The results will be helping in streamlining socially acceptable management programmes to address the problem of climate change.

Limitations of the study

The present research work is a part of post graduate programme which has all the limitations of time, finance, mobility and other resources. The study was restricted to *Kuttanad* and *Kole* lands – the major rice growing tracts of Kerala. So it may not be possible to generalize the findings of the study for the entire state and can be taken as indicative in nature. Major part of socioeconomic data was drawn from the farm diaries maintained by the farmers. The weather data were collected from the Meteorological stations at Rice Research Station, Mancompu (for *Kuttanad*) and College of Horticulture, Vellanikkara (for *Kole*). The weather data, especially that for Kole areas may not strictly represent the ecosystem of Kole, since the Meteorological station lies nearly 20 kilo metres from *Kole*. In spite of these limitations, every efforts were made by researcher to carry out the study as systematic as possible.

Presentation of the thesis

The thesis is divided into five chapters. The present chapter gives the introduction of the research problem, covers the scope, objectives and limitations of the study. The second chapter deals with review of literature, relevant to the study. The third chapter details the study area, the methodological frame work, analytical tools and conceptual issues. The fourth chapter narrates the results obtained and also discusses the results in detail. The fifth and final chapter presents the summary and policy prescriptions based on the study. The references and abstract of the thesis are given at the end.

REVIEW OF LITERATURE

Chapter II

Review of Literature

"Warming of climate system is now unequivocal, as is now evident from observations of increase in global average air and ocean temperatures, widespread melting of snow and ice and rise in global sea level." (IPCC, 2007).

Climate change has become a major concern to human society because of its potentially deleterious impact worldwide, through its effect on different economic sectors. It poses significant threat to sustainable development in developing countries, which have fewer resources and are more vulnerable (Munasinghe, 1997). Impacts on developing countries remain poorly understood because few studies have successfully measured the effect of climate change on developing country economies. Nonetheless, it is likely that a developing country will be more vulnerable because a greater fraction of its economy is in climate sensitive sectors (for example, agriculture), and it is already in a hot climate zone and the economy relies on labour intensive technologies with fewer adaptation opportunities (Mendelsohn *et al.*, 2001).

Agriculture is one of the most vulnerable sectors to the anticipated climate change. Despite the technological advances in the second half of 20th century, including the green revolution, weather and climate are still key factors in determining agricultural productivity in most areas of the world. The predicted changes in temperature and rainfall patterns, their associated impacts on water availability, pests and disease, and extreme weather events are likely to affect substantially the potential of agricultural production. Literature on the economics of climate change suggests that, although global crop production may be boosted slightly by global warming in the short term (before 2030), it will ultimately turn negative over the long run (Bruinsma, 2003; IPCC, 2007). Moreover, the impact of climate change on agricultural production is unlikely to be evenly distributed across regions. Low latitude and developing countries are expected to suffer more from the agricultural effects of climate change and global warming, reflecting their disadvantaged geographic location, greater agricultural share in their economies, and limited ability to adapt to climate change. In contrast, crop production in high latitude regions will generally benefit from climate change. In a global comprehensive estimate for over 100 countries, Cline (2007) predicted that global agricultural productivity would fall by 15.9% in the 2080s if climate change and global warming continues unabated, with developing countries experiencing a disproportionately larger decline of 23.6 per cent (World Bank, 2008).

Climate can affect agriculture in variety of ways. Temperature, radiation, rainfall, soil moisture and carbon dioxide (CO_2) concentration are all important variables to determine agricultural productivity, and their relationships are not simply linear. Current research confirms that there are thresholds for these climate variables above which crop yields decline (Challinor *et al.*, 2005; Proter and Semenov, 2005). For example, the modeling studies discussed in recent IPCC reports indicate that moderate to medium increases in mean temperature (1–3°C), along with associated CO_2 increases and rainfall changes, are expected to benefit crop yields in temperate regions. However, in low-latitude regions, moderate temperature increases (1–2°C) are likely to have negative yield impacts for major cereals. Warming of more than 3°C would have negative impacts in all regions (IPCC, 2007).

The interaction of temperature increases and changing rainfall patterns determines the impact of climate change on soil moisture. With rising temperatures, both evaporation and precipitation are expected to increase. The resulting net effect on water availability would depend on which force is more dominant. Lonergan *et al.* (1991) studied the impacts of climate change on various sectors and their assessment was that there is an impact of climate change on the key river systems and indirectly will affect cropping and all other socioeconomic systems in Asia. Jose and Cruz (1999) studied the impacts of climate change on the water resources of Philippines and found that the country is highly vulnerable to global climate change especially the warming and it would create a threat on the water resources of the country. Possible measures to cope with future problems due to water scarcity has to be assessed and strengthened. Soudi Arabia is another country, which is going to affect by the increasing temperature and decreasing precipitation and thus leading to the water scarcity (Alkolibi,2002). The IPCC reports project that by the middle of the 21st century, water availability will increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics (IPCC, 2007). Some regions that are already drought-prone may suffer more severe dry periods.

Increases in atmospheric CO_2 concentration can have a positive impact on crops yields by stimulating plant photosynthesis and reducing the water loss via plant respiration. This carbon fertilization effect is strong for so-called C3 crops, such as rice, wheat, soybeans, fine grains, legumes, and most trees, which have a lower rate of photosynthetic efficiency. For C4 crops like maize, millet, sorghum, sugarcane, and many grasses, these effects are much smaller. Other factors such as a plant's growth stage, or the application of water and nitrogen, can also impact the effect of elevated CO_2 on plant yield. Recent research based on experiments with the free air concentration enrichment method suggests a much smaller CO_2 fertilization effect on yield for C3 crops and little or no stimulation for C4 crops, in comparison with past estimates from studies conducted under enclosed test conditions (Long *et al.*, 2000). Based on analysis of data, the IPCC reports suggest that yields may increase by 10–25% for C3 crops and by 0–10% for C4 crops when CO_2 levels reach 550ppm (IPCC, 2007). However, as a number of limiting factors were not included in the modeling and experiment analysis, considerable uncertainties still surround the estimates of carbon fertilization effect.

Globally there are a number of studies on the impacts of climate change on the cereal production. Wang *et al.* (1992) conducted the response studies of wheat in Australia in the context of changing climate and found that the yield ranges from -34 to +65 per cent. Seino (1993) observed that there is a negative impact on the rice production scenario at the southern parts of Japan like the negative impacts of rice due to climate change in the South and South East Asian countries.

Matthews *et al.* (1997) studied the yield changes in rice, wheat and maize in South Asian countries. He projected the yield changes at -3 per cent to +28 per cent for India, +2 per cent to +27 per cent for Malaysia, -14 per cent to +14 per cent for Philippines and -18per cent to -4 per cent for mainland China. The study concluded that there must be severe yield loss in South Asia and South East Asia for these crops due to high temperature effect leading to spikelet sterility. Similar estimates were made by Brklaich and Smit (1992), Brklaich *et al.* (1994) and Rosenzweig and Parry 1994), for wheat and soybean yield of United States and Canada. They found that there is a chance for total or near total crop failure, every year projected for wheat and soybean at one site in the US but wheat yield increases about 180 to 230 per cent for other sites in the US and Canada.

Reilly *et al.* (1996) had studied the impact of climate effects on the production of crops like rice, wheat, maize, millets and soybean. He concluded that, tropical areas as more likely to suffer the negative consequences of climate change. In Europe, United States and Canada, Asia, Pacific regions, where more studies were conducted, the results generally range from severe negative effects (-60 per cent, -70 per cent, or complete crop failure) to equally large potential yield loss.

Iglesias *et al.*(1996) reported that the production of rice generally did not benefit from climate change in Asia. Ramakrishnan (1998) found that, rainfall will increase in areas of Asia Pacific up to 50 per cent. In that case, Indonesian paddy cultivation would face a predicted lower yield in the first as well as in the second crop season, if the country won't focus on the adaptation strategies. Increase in solar radiation by a minimum of 1.2 to 2.1 per cent and an increase in rainfall by 7 to 9 per cent will have a serious impact on the agricultural sector of the region. Increasing population, decreasing land for cultivation are major problems in the country, which got more adverse with the impacts due to extreme weather events and associated problems due to climate change (Amien *et al.,* 1999).

Luo *et al.* (1999) opined that changes in averages climate conditions and climate variability will have a significant consequence on crop yields in many parts of the region. Crop yield and productivity changes will vary considerably across the region. Vulnerability to climate change depends not only on physical and biological response but also on socioeconomic characteristics.

Murdiyarso (2000) also reported the impacts of climate change the potential rice production in Asia. Collaborative studies carried out by IRRI and US-EPA reported that using process-based crop simulation models increasing temperature may decrease rice potential yield up to 7.4 per cent per degree increment of temperature. When climate scenarios predicted by GCMs were applied it was demonstrated that rice production in Asia may decline by 3.8 per cent under the climate of the next century. Moreover, changes in rainfall pattern and distribution were also found suggesting the possible shift of agricultural lands in the region.

Lobell *et al.*(2011), published a study of worldwide crop yields for the major staple crops corn, rice, soybeans and wheat. In general, crop yields decreased during recent times when compared to 1960-2000. The impact is profound for the wheat crop in Russia, which declined on average about 13% (1980-2008). Over this interval the atmospheric content of the greenhouse gas carbon dioxide was increasing, and global temperature was also increasing. The authors correlated the decreasing yield with warming climate trends.

Some other ecological changes brought on by global warming will also have an impact on agriculture. For example, the patterns of pests and diseases may change with climate change, leading to reductions in agricultural production. Moreover, agricultural productivity will be depressed by increased climate variability and increased intensity and frequency of extreme events such a drought and floods. These factors further contribute to the difficulties in estimating the impacts of climate change on agricultural productivity.

Mainly three approaches are followed for quantifying the impacts of climate change on agriculture. The Crop Simulation models, Agro Economic Zone models (AEZ) and the Ricardian models. The Ricardian models rely on farmer level production and socioeconomic variables and this accommodates the farm level adaptation strategies.

This approach for assessing the impacts of climate change in agriculture was first tried by Mendelsohn *et al.*, (1994) United States. Farmland prices and net revenues were regressed on climate, soil and other production variables. Much of the data used related to countywide averages, and spatial statistical techniques were used to construct countywide climatic variables from weather station data. The quadratic climate terms were significant, indicating a nonlinear relationship between farm value and climate. Cline (2007) used both Ricardian statistical models and crop models to develop a set of consensus agricultural impact estimates through the 2080s for over 100 countries. He first developed geographically detailed projections for changes in temperature and precipitation through the 2080s based on a baseline emission projection from the IPCC's emission scenarios. Next, these climatic change projections were applied to the agricultural impact models to assess the effects of climate change on agricultural productivity. Cline found that agricultural production in developing countries may fall between 10 to 25 per cent if global warming progressesd unabated, and India's agricultural capacity could be less by 40 per cent.

On similar lines, Kumar and Parikh (1998) analyzed the climate change impacts on Indian agriculture, defining the variables to suit Indian conditions. District level estimates of annual net revenues were regressed on climate and other socio-economic variables. They found that there will be $2^0C - 4^0C$ increase in temperature and 7-14 per cent increase in precipiation and it would cause a decline in yield of rice and wheat by 15 per cent and 42 per cent respectively.

Mendelsohn *et al.* (2001) have compared climate sensitivity of the US, Brazilian and Indian agriculture using the estimates based on the Ricardian approach and has argued that using the US estimates for assessing climate change impacts on Indian agriculture would lead to under-estimation of impacts. Later, Kumar and Parikh (2001) predicted a 10 percent loss in farm level net revenue with a 2^oC temperature rise and seven percent increase in rainfall. Mall *et al.* (2006) provide an excellent review of climate change impact studies on Indian agriculture mainly from physical impact perspective. The available evidence shows significant drop in yields of important cereal crops like rice and wheat under climate change conditions. Sanghi and Mendelsohn (2008) have used a variant of the Ricardian approach and showed that the regional differences are significantly large with Northern and Central Indian districts along with coastal districts bearing relatively large impact. However, biophysical impacts on some of the important crops like sugarcane, cotton and sunflower have not been studied adequately (Kumar, 2009).

In Brazil, Sanghi (1998) conducted a Ricardian study using district averages for net revenues and land values. They concluded that the impact of climate change on agricultural productivity as negative, with the most pronounced impacts being felt in the central and western regions.

Maddison (2000) employed the Ricardian model for England and Wales, using actual sale price at the level of the individual farm to determine the economic impact of climate change in agriculture. They reported that the number of frost days in winter had a significant influence on farm income. Maddison (2000) also found that the price per hectare of land depends strongly on the size of the farm. Carter and Christopher (1991), Hartig *et al.* (1997) and Jones and Thornton (2003) also have studied the impact of climate change in European agriculture and found the adverse effects of climate change in the agricultural sector.

Using census tract data, Reinsborough (2003) examined the extent to which climate explains variation in farm values and farm net revenues for Canada. The results are of particular interest because Canadian agriculture arguably stands to benefit from global warming. Reinsborough reported that climate variables are statistically significant along with latitude and population density, but that the potentially beneficial impacts of climate change cannot be ascertained with any degree of precision.

Seo *et al.* (2005) attempted the climate impact valuation on Srilankan agriculture using Ricardian approach. The model examined the net revenue per hectare of the four most important crops in the country. The limited range of temperature variation allows only a simple test of temperature impacts, but the greater range of precipitation across the country distinguishes more complex precipitation effects. The impacts vary from –11 billion rupees (–20 per cent) to +39 billion rupees (+72 per cent) depending on the climate scenarios. With warming, the already dry regions (the Northern and Eastern provinces), are expected to lose large portions of their current agriculture, but the cooler regions (the central highlands), are predicted to remain the same or increase their output.

Maddison *et al.*(2007) and Kurukulasuriya and Mendelson (2008) have attempted the Ricardian approach on agriculture of Africa by studying the climate change and its impact on eleven African countries (Kenya, Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Niger, Senegal, South Africa, Zambia and Zimbabwe) by relying upon the farm data conducted by survey of over 9500 farmers. Annual net revenue was regressed on climate and other variables. The study confirmed the current climate effects on the net revenues of farms across Africa. Applying these results to possible future climate changes revealed that dryland farms as especially climate sensitive. Even as early as 2020, climate change could have strong negative impacts on currently dry and hot locations. By 2100, dryland crop net revenues could rise by 51per cent if future warming is mild, but fall by 43 per cent if future climates are hot and dry. The crop net revenues of currently irrigated farms are likely to be least affected.

A study was conducted in Nepal by Thapa *et al.* (2010), based on Ricardian approach to measure the relationship between net farm income and climate from more than 656 households of 15 districts covering all ecological belts (mountain, hills and Terai). Net farm income is regressed on climate, household and economic variables. The findings show that these variables have impact on the net farm income. More specifically, summer and fall precipitations have negative impact, while winter temperature and precipitation have positive impact on the net farm income. Net farm income is found to be positive to the households having higher ratio of irrigated farm land, receiving farm credit, higher number of livestock, lower distance of input markets and higher level of head's education. The marginal impact analysis reveals that marginally increasing precipitation during spring and summer would reduce net farm income per hectare and marginally increasing temperature during the winter would increase net farm profit.

Conclusively, the impact of climate change on agriculture in Nepal seems to be varied with the temperature and precipitation in different agro-ecological zones. Farmers are likely to increase their revenue with relatively low temperature and enough precipitation during the summer period. Other socio-economic variables have also impact on net farm income. For instance, net farm income is likely to be high on irrigated farm land combined with obtaining farm credit. But small farms manage better and obtain higher net income per hectare than large farms.

Studies on climate variability

Extreme climate events are a source of mounting concern across the world. The impact of weather and climate extremes can be severe and wide-ranging although, in some cases, the impact can also be beneficial. Weather and climate extremes affect all sectors of the economy and the environment, including human health and well-being.

The term "weather extremes," signifies individual weather events that are unusual in their occurrence (minimally, the event must lie in the upper or lower ten percentile of the distribution) or have destructive potential, such as hurricanes and tornadoes. The term "climate extremes" is used to represent the same type of event, but viewed over seasons (e.g., droughts), or longer periods (Karl *et al.,* 2008).

In recent decades, the number of people affected by climate disasters such as droughts, floods and storms has been rising. Climate change will further increase the risk of exposure to climate disaster (Human development Report, 2007-08). The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) pointed out that climate change and its variability will exacerbate existing vulnerabilities to droughts and floods in Asia. Tropical cyclones can become more intense. Combined with sea-level rise, this would result in enhanced risk of loss of life and properties in coastal low-lying areas of cyclone-prone countries. Increased precipitation intensity, particularly during the summer monsoon, can contribute to increase in flood events. At the same time, drier summer conditions in arid and semi-arid areas can lead to more severe droughts. The economic loss due to these extreme weather events affect the development pace of the nations.

Studies by made by Ungar (1999), Obassi (2001) and De (2005) have shown that, globally, losses due to extreme events are increasing steeply specially in the last decade of the twentieth century. In recent years the global loss of US $ 50-100 billion annually are caused due to these natural hazards together with the loss of life, which is about 2,50,000 (De, 2005). However, these increased losses may be either due to a real increase in the frequency of the extreme weather events or due to increased vulnerability of cities, towns and the associated infrastructure and installations which have grown rapidly to meet the needs of a growing population.

Kelkar and Bhadwal (2007) studied the impact of climate change as well as the variability of climate change and its impacts on different sectors of South Asian countries like Bangladesh, Bhutan, India, Nepal, Sri Lanka, Malidives and Pakistan. They reported that extreme events of rise in temperature and changes in rainfall patterns will have adverse impacts on agricultural production in these countries.

IPCC (1999) report for Indian Subcontinent opined that, climatic variability and occurrences of extreme climate events are more important in India. The rainfall fluctuations in India have been largely random over a century with no systematic change detectable in summer monsoon (Mall *et al.*, 2006). Extreme weather conditions create crop loss, if the crop is at the critical stage of development. Reduction in rainfall will reduce irrigation water availability and leads to lesser yields. Nearly 18 per cent reduction in grain output was observed after the climate variation in 2002-03. The inter annual monsoon variations has lead to extreme conditions of floods and droughts in various parts of India, causing severe damages to the food grain output (Parthasarathy and Pant,1985; Parthasarathy *et al.*,1992; Selvaraju,2003; Kumar *et al.*, 2003 and Kumar and Balasubramaniam, 2010). Climatic extremes, thus causes impacts on economy due to changes in output, income and savings. Variations in regional economic growth patterns are also observed due to the rippling and multiplier effects of climate extremes (World Bank, 2008).

Ali (1996, 1999) and Mirza *et al.* (2003) and reported Bangladesh as one of the very prone countries of climate change in Asia. All the studies concluded that substantial changes in rice agriculture of the country. Increased flood will inundate 70 per cent of area of Bangladesh and will cause serious damage to the economy of the country. Climate change will increase the sea surface temperature of the region to 2^0C to 4^0C, this also cause extreme climate events.

Aiwen (2000) opined that the annual average temperature of China will increase by 0.88 to 1.2^0C by the year 2030. The runoff will rise by 6 per cent, and thus increasing the water shortage in the region and so the associated socioeconomic problems. Erda (1996) reported that if China won't accommodate the annual incremental cost for adaptation to climate change of US$0.8 to 3.48

billion, the agricultural loss due to global climate change would be US$1.37 to 79.98 billion from 2000 to 2050.

Sri Lankan island will experience extreme rainfall intensities and warmer temperatures as a result of climate change. It is predicted that there is a possibility for 10 per cent increase in the length of dry and wet seasons. Sri Lanka is clearly vulnerable to predicted climate change and subsequently greater economic, social and environmental problems (Wijeratne, 1996). Studies conducted at different sectors of other South East Asian countries like Taiwan, Vietnam, Yemen, Kazakhstan and Pakistan by various scientists reported that these countries are vulnerable to climate change either due to increased temperature or due to increased/ decreased rainfall and /or to both. The extreme weather events are also becoming common in these countries. This affect the water, forest and agrarian scenario of the respective countries thus leading to irrevocable impacts on the society (Pilifosova *et al.,* 1997 Alderwish and Mohamed 1999; Booth *et al.,* 1999; Siddiqui *et al.,* 1999 and Yu *et al.,* 2004 respectively).

Climate change is projected to impinge on the sustainable development of most developing countries of Asia, as it compounds the pressures on natural resources and the environment associated with rapid urbanisation, industrialization, and economic development. It is projected that crop yields could increase up to 20% in East and South-East Asia while they could decrease up to 30% in Central and South Asia by the mid-21st century. Taken together and considering the influence of rapid population growth and urbanisation, the risk of hunger is projected to remain very high in several developing countries.

The Stern's Review on the Economics of Climate Change(2006) estimated that that if we don't act, to avert the climate change effects, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year. Thus, investing on adaptive strategies to minimize climate change impacts create further burden on already scarce resources of the de4veloping economies.

The Fourth Assessment Report of IPCC (2007) reports that, globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-

3°C, but above this it is projected to decrease. Increases in the frequency of droughts and floods are projected to affect local crop production negatively, specially in subsistence sectors at low latitudes. Adaptations such as altered cultivars and planting times allow low- and mid- to high-latitude cereal yields to be maintained at or above baseline yields for modest warming. Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s.

Review on Panel Data Analysis

Panel data analysis is a method of studying a particular subject within multiple sites, periodically observed over a defined time frame. Panel data analysis endows regression analysis with both a spatial and temporal dimension. The spatial dimension pertains to a set of cross-sectional units of observation. These could be countries, states, firms, commodities, groups of people, or even individuals. The temporal dimension pertains to periodic observations of a set of variables characterizing these cross-sectional units over a particular time span. With repeated observations of enough cross-sections, panel analysis permits the researcher to study the dynamics of change with short time series. The combination of time series with cross-sections can enhance the quality and quantity of data in ways that would be impossible using only one of these two dimensions (Gujarati, 2004). Panel data analysis can provide a rich and powerful insight into the issues, if one is willing to consider both the space and time dimension of the data. Panel data analysis allows for individual heterogeneity explicitly, by allowing individual specific variables. It provides more informative data, more variability, less collinearity among variables, more degrees of freedom and more efficiency (Gujarati, 2004). It is found that Mendelsohn *et al.*, (1994), Kumar and Parikh (1998) and Kumar (2009) have attempted the panel data analysis on climate change studies in their respective study areas.

MATERIALS AND METHODS

Chapter III

Materials and Methods

This chapter describes the details of the study area, the subjects and the farming situations. The method of sample selection, data collection and analysis is detailed.

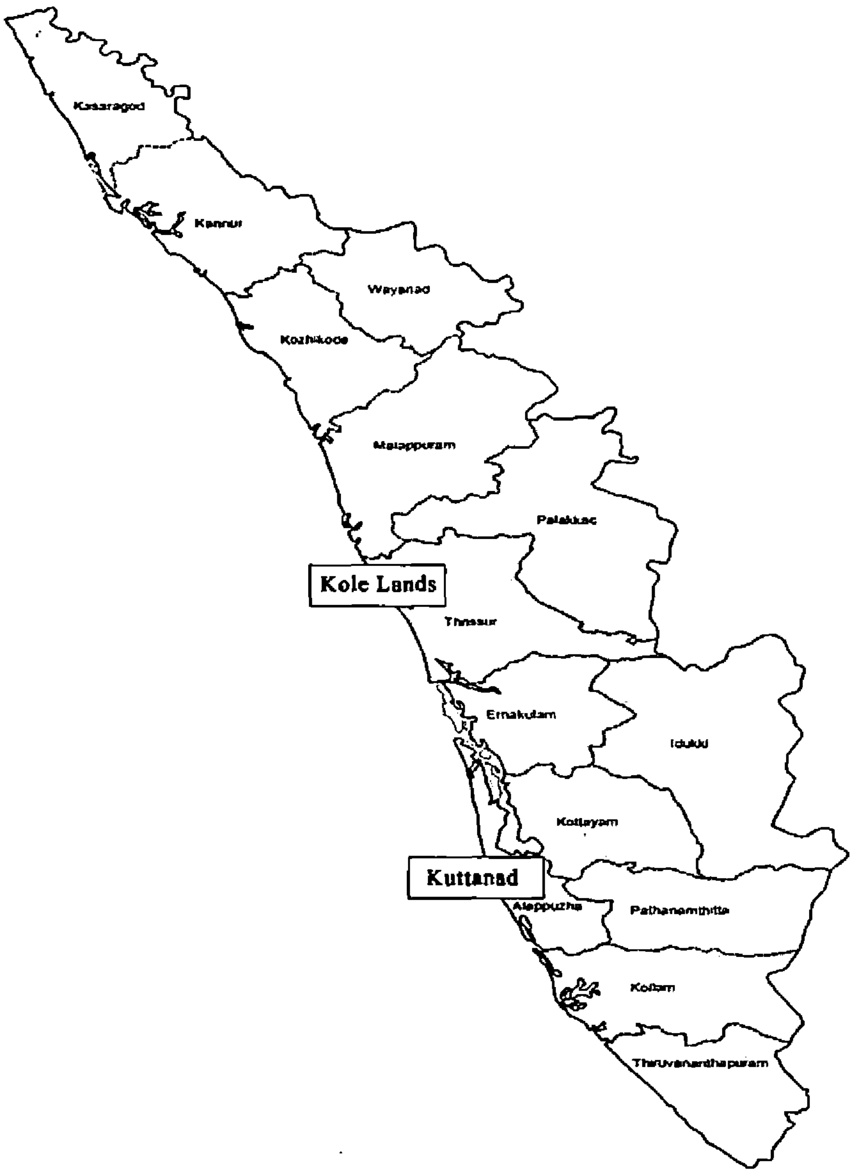
3.1. THE STUDY AREA

The major rice growing tracts in Kerala are *Kuttanad* and *Kole*, which together contribute for 26.50 per cent of total rice area and 29.84 per cent of total rice production. The area demarcated as *Kuttanad* is spread over three districts viz. Alappuzha, Kottayam and Pathanamthitta, with an area of 55,000 ha. Of this, sizable portion is (55 per cent) in Alappuzha district and hence, the district was selected to represent *Kuttanad* (Fig.3.1.1). *Kuttanad* lies below the Mean Sea Level and hence is a unique production system. Inhabited lands are about two to four feet below the sea level and the rice fields about ten feet below. *Kuttanad* is also the merging point of several rivers such as Pamba, Achankovil, Manimala and Meenachil. These rivers join to form a vast expanse of water called the Vembanad lake which encircles Kuttanad.

Within the Vembanad-Kole wetland ecosystem, the *Kole lands* cover an area of about 13,632 ha. spread over Thrissur and Malappuram districts. 83 per cent of the *Kole* area is in Thrissur district. So, Thrissur district was selected for the study to represent *Kole* lands (Fig.3.1.1). *Kole* in the regional language Malayalam indicates bumper yield or high returns, though the risk level is very high. Similar to *Kuttanad* ecosystem, *Kole* lands are also 0.5 to 1 mere below MSL (Binilkumar, 2010). The rice ecosystem in *Kuttanad and Kole* were focused for the study.

Multi stage Random Sampling Method was adopted for sample selection. One block, Panchayat, and *Padasekharams* in the selected districts were randomly identified. Thus, Ayyanad, Nedumudi, Champakkulam, Viyapuram, and Kainakary in *Kuttanad* and Adat and Chittilappilly in *Kole* lands were identified.

Fig.3.1.1. Political Map of Kerala Showing the Study Area



3.2.Data Sources :

3.2.1.Primary Data

This study is based on both primary and secondary data. The primary data was gathered from respondent farmers. The farmers who had been in rice farming for a fairly long period of time and who regularly kept record of their activities (25-30 years) were identified. For this purpose, the following institutions/ organizations were contacted.

1. Department of Agriculture, Govt. of Kerala
2. Kerala Agricultural University (RRS, Mancompu)
3. Service Cooperative Societies in the study area
4. Farmer's organizations (*Padasekhara samithies*)/ Self Help Groups
5. Local leaders/ Fertilizer retail traders/ Farm workers etc.

After a preliminary examination of the records maintained and the willingness of the farmer to share the information, 35 farmers were identified as sample respondents from *Kuttanad* and *Kole* areas each. One sample was deleted later on, from *Kuttanad*, due to want of complete information. Thus the sample size was 34 from *Kuttanad* and 35 from *Kole*. The cultivation details, input use level, planting time, management practices and the yield and returns were compiled from the diary maintained by the farmers, for the period from 1980 to 2008, for the puncha crop (Summer crop) .The details of farming practices were described on a daily basis in these diaries and the required information were sorted and were compiled .

The data pertaining to the socio- economic information of the farmers, current holding size, cropping pattern, yield and return, attitude, awareness regarding climate change and responses to climate change were collected by personal interview method using pre tested structured interview schedule (Appendix I). A pilot study for this purpose was conducted for developing the final interview schedule. The survey was conducted during the period from November 2010 to February 2011.

3.2.2. Secondary Data

The Department of Economics and Statistics conducts regular surveys to assess the cost of cultivation and returns of rice farming in Kerala. They publish the district wise data, following the methods adopted by the CACP (Commission for Agricultural Costs and Prices). The data from 1980- 2008 for the state as whole and for the districts of Alappuzha and Thrissur were compiled. *The Kole Sahakarana Sangham* (a Cooperative Society of *Kole* farmers) were also maintaining the data on paid out costs and returns of cultivation, and data for a period 1980-

2008, was gathered from them. Thus there were three complete sets of time series data on various cost and returns in rice farming, in *Kole* lands and two sets in *Kuttanad* i.e.

1. Data from Department of Economics and Statistics (State level and District level)
2. Data from *Kole Sahakarana Sangham* (for *Kole*)
3. Data from respondent farmers (*Kuttanad* and *Kole*)

Thus the primary data set constituted the panel data of 34 farmers for 28 years in *Kuttanad* and of 35 farmers for 28 years in *Kole.*

One of the objectives of the study was to assess the public cost of expenditure towards the damages due to weather extremes in *Kuttanad* (summer rain, 2008). The extreme weather related disaster cause great loss to the economy which include the public expenditure towards disaster management and the private loss suffered by the victims. For assuming the public cost of extreme weather event (summer rain, 2008), the extent of compensation provided by the Government of Kerala to the paddy farmers in Alappuzha was gathered. The information includes the compensation payment towards complete crop loss, partial damage and quality loss. These were collected separately from the records maintained at Principal Agricultural Office, Alappuzha, Government of Kerala.

3.3. Analytical framework

Quantitative estimates of the agricultural impact of climate change have predominantly relied on three approaches: crop simulation models, agro-ecological zone (AEZ) models, and cross-section (Ricardian) models. Crop simulation models draw on controlled experiments where crops are grown in field or laboratory settings simulating different climates and levels of CO_2 in order to estimate yield responses of a specific crop variety to certain climates, and other variables of interest. These models do not include farmer adaptation to changing climate conditions in the estimates. Consequently, their results tend to overstate the damages of climate change to agricultural production (Mendelsohn and Dinar, 1999).

The second approach, AEZ analysis, combines crop simulation models with land management decision analysis, and captures the changes in agro-climatic resources (Darwin *et al.,* 1995; Fishcher *et al.,* 2005). AEZ analysis categorizes existing lands by agro-ecological zones, which differ in the length of growing period and climatic zone. The length of growing period is defined based on temperature, precipitation, soil characteristics, and topography. The changes of the distribution of the crop zones along with climate change are tracked in AEZ models. Crop modeling and environmental matching procedures are used to identify crop specific environmental limitations under various levels of inputs and management conditions, and provide estimates of the maximum agronomically attainable crops yields for a given land resources unit. However, as the predicted potential attainable yields from AEZ models are often much larger than current actual yields, the models may overestimate the effects of autonomous adaptation. Cline (2007) observed that AEZ studies tend to attribute excessive benefits to the warming of cold high-latitude regions, thereby overstating global gains from climate changes.

The Ricardian cross-sectional approach explores the relationship between agricultural capacity (measured by land value) and climate variables (usually temperature and precipitation) on the basis of statistical estimates from farm survey or country-level data. This approach automatically incorporates efficient climate change adaptations by farmers. In the Ricardian approach, instead of studying yields of specific crops under different controlled settings, we examine how climate in different places affects the rent or revenue from farm land. By directly measuring rents, we take into account direct impacts of climate on yields of different crops as well as the potential for substitution of different inputs, introduction of different activities, and other potential adaptations to different climates. For example, by changing seed, irrigation, harvest length, or fertilizer, a farmer might adjust to changes in climate in ways that crop- yield models may fail to measure. If markets are functioning properly, the Ricardian approach will allow us to measure the economic value of different activities and therefore to verify whether the economic impacts implied by the crop yield experiments in the production – function approach are reproduced in the field (Mendelsohn, 1992). The major criticisms of the Ricardian approach are its ignorance of price changes and that it fails to fully control for the impact of other variables that affect farm incomes (Cline 1996; Mendelsohn and Dinar, 1999).

Kumar (2010) opines that even this approach, does not fully accommodate the adaptation strategies when the observed climate change difference is much larger than the expected. Further, the issues concerning cost of adaptation are not fully addressed. However, Kumar and Parikh (2001), Mendelsohn *et al.* (2001), and Sanghi and Mendelsohn (2008) have employed the Ricardian approach and its variants to quantify the effect of climate change on farm revenue.

Ricardian approach, like hedonic property model in Environmental Economics, makes use of the changes in land rent/ values to capture the effect of climate change (Mendelsohn, 1994). Due to the imperfect market condition that exists for land markets in most of the developing countries, farm land revenue is taken as a market indicator, in the place of land value (Dinar *et al.*,1998; Kumar, 2009). Hence in most of the studies, where Ricardian model is followed in developing countries, Net Farm Revenue is taken as the dependant variable. In this study the method followed by Kumar (2009) is adopted with appropriate changes to suit the study area and socioeconomic scenario.

Model Specification:

The model, in this study is specified as

$FBI_{it} = f(S,C)$

FBI_{it} = Farm Business Income of the i^{th} farmer during t^{th} timeperiod

and S indicate socioeconomic variables and C climate variables

FBI_{it}	=	f(AREA, AGE, EDN ,$MaxT_1$, $MaxT_2$, $RAIN_1$, $RAIN_2$)
FBI_{it}	=	Farm Business Income [FBI=Gross Returns – Cost A_1(Rs)]
$AREA_{it}$	=	Area under cultivation of paddy (puncha) in cents
AGE_{it}	=	Age of farmers (years)
EDN_{it}	=	Education of the respondent farmer (number of years of schooling)
$MaxT_{1it}$	=	Maximum temperature in the first half of cropping season (mean of November –December temperature in ^{0}C)
$MaxT_{2it}$	=	maximum temperature in the second half of cropping season (mean of January- February temperature in ^{0}C)
$MaxR_{1\,it}$	=	Rainfall in the first half of cropping season (mean rainfall of November – December in cm)
$MaxR_{2it}$	=	Rainfall in the second half of cropping season(mean rainfall of January- February in cm)

Panel data analysis is a method of studying a particular subject within multiple sites, periodically observed over a defined time frame. Panel data analysis endows regression analysis with both a spatial and temporal dimension. The spatial dimension pertains to a set of cross-sectional units of observation. These could be countries, states, firms, commodities, groups of people, or even individuals. The temporal dimension pertains to periodic observations of a set of variables characterizing these cross-sectional units over a particular time span. With repeated observations of enough cross-sections, panel analysis permits the researcher to study the dynamics of change with short time series. The combination of time series with cross-sections can enhance the quality and quantity of data in ways that would be impossible using only one of these two dimensions (Gujarati, 2004). Panel data analysis can provide a rich and powerful insight into the issues, if one is willing to consider both the space and time dimension of the data. Panel data analysis allows for individual heterogeneity explicitly, by allowing individual specific variables. It provides more informative data, more variability, less collinearity among variables, more degrees of freedom and more efficiency (Gujarati, 2004).

The panel data comprising 34 observations for *Kuttanad* and 35 observations for *Kole*, each of 28 years were used for this analysis. The data set is thus an unbalanced panel, as some of the respondent farmers started the book keeping after 1980, or they could not locate their diary or they did not raise the crop in some years. Separate equations were estimated for *Kuttanad* and *Kole* region.

The analysis was done using the statistical package STATA. The Hausman test was done to decide between random effects and fixed effects model. The null hypothesis in this, is that the preferred model is Random effect model (that is unique errors are not correlated with regressors). The averages, percentages and estimates of growth trends are also used in the analysis.

RESULTS AND DISCUSSION

Chapter IV

Results and Discussion

Results of the study are presented under four major sections:-

4.1. Socio economic profile of the respondent farmers in the study area

4.2. Paddy production status in Kerala

4.2.1. Paddy farming practices in the study area

4.2.2. Economics of paddy production

4.2.3. Climate and paddy production

4.2.4. Economic impact of climate change

4.3. Public cost of weather extremes

4.4. Farmer's perception and adaptive behaviour to climate change

4.1. Socio Economic Profile of the Respondent Farmers in the Study Area

The general social and economic status of the respondent farmers is furnished in table 4.1.1. As is the general demographic pattern in Kerala, majority farmers belong to the 31-60 years followed by the older age group of more than 60 years. The average age was 57 years, which was same in the two groups. The reluctance of younger generation to opt agriculture as a vocation has been reported by many authors (Kannan, 2000).

The nuclear family system in Kerala is reflected in the average family size of 5.75 (with a range of 5-7) across the regions, thus limiting the scope of family labour involvement in agriculture. Devi (2011) also reported this while analyzing the labour use pattern in paddy cultivation.

Kerala state is known for the high literacy rate (94 per cent) compared to rest of India. All the sample farmers were able to read and write and majority of them (70 per cent) have studied up to 10th standard. Four percent had University level education. Educational status can be considered as a strong support for agricultural extension mechanism and can act as a driver for agricultural development through better technology adoption, adaptive strategies and mitigation strategies for risk management.

Kuttanad is known for its agricultural activities especially rice cultivation. Hence 50 per cent of respondents in the area depend on agriculture alone for the livelihood. But in Kole areas, agriculture is the main, not sole, occupation for 40 per cent, and subsidiary for 31 per cent. Only for 29 per cent, agriculture is the sole source of income.

59.18 lakh operational land holdings in Kerala are marginal (< 1ha.) i.e. 94 per cent. (Farm Guide, 2011). Among the sample farmers, 43 per cent belong to this category, followed by one third in the 1-2 ha category. The average holding size is 1.89 ha.

Table 4.1.1. Socio economic profile of the respondent farmers in the study area

I. Age group (years)	No. of farmers (Kuttanad)	No. of farmers (Kole)	Aggregate value
18- 35	2 (6)	4 (11)	6 (9)
36-60	19 (56)	23 (66)	42 (61)
> 60	13(38)	8 (23)	21 (30)
Total	34 (100)	35 (100)	69 (100)
Average Age	57	57	57
II. Family size (Number)	**No. of farmers (Kuttanad)**	**No. of farmers (Kole)**	**Aggregate value**
2-4	4 (12)	-	4 (6)
5-7	30 (88)	35 (100)	65 (94)
Total	34 (100)	35 (100)	69 (100)
Average family size	5.7	5.8	5.75

; 4.1.1. Socio economic profile of the respondent farmers in the study area (Cont..)

III.Education	No. of farmers (Kuttanad)	No. of farmers (Kole)	Aggregate value
Illiterate	0 (0)	0 (0)	0 (0)
Primary	5 (15)	4 (11)	9 (13)
Up to tenth	24 (71)	27 (77)	51 (74)
Higher Secondary	3 (9)	5 (14)	8 (12)
Graduation and Above	2 (6)	1 (3)	3 (4)
IV. Occupation	**No. of farmers (Kuttanad)**	**No. of farmers (Kole)**	**Aggregate value**
Agriculture only	17 (50)	10 (29)	27 (39)
Agriculture as main occupation	11 (32)	14 (40)	25 (36)
Agriculture as subsidiary occupation	6 (18)	11 (31)	17 (25)
Total	34 (100)	35 (100)	69 (100)
V. Holding size	**No. of farmers (Kuttanad)**	**No. of farmers (Kole)**	**Aggregate value**
< 1 ha.	16 (47)	14 (40)	30 (43)
1-2 ha.	13 (38)	10 (29)	23 (33)
2-4 ha.	4 (12)	8 (23)	12 (17)
>4 ha.	1(3)	3 (9)	4 (7)
Total	34 (100)	35 (100)	69 (100)
Average holding size	1.93	1.84	1.89

4.2. Paddy Production Status in Kerala

Paddy cultivation is part of the proud culture of Kerala State. It is the most important cereal and staple food produced and consumed in Kerala. This fact has given it a very important position in the state's agriculture. Paddy was cultivated in almost all parts of Kerala, in three seasons *Viruppu* (Autumn), *Mundakan* (Winter), and *Puncha* (Summer). Currently (2010), 32.70 per cent of the output is from *Virippu*, 42.20 per cent from *Mundakan* and 25.10 per cent from *Puncha*. *Kuttanad*, *Kole* and Palakkad are the major growing centres of the crop. Of the total output, 17.70 per cent is from *Kuttanad*, which is known as the rice bowl of Kerala, followed by 12.20 per cent from *Kole* and 14.20 per cent from Palakkad. The remaining part is from the paddy farms located in other parts. *Mundakan* season accounts for highest share in production with 45.51 per cent followed by 32.10 per cent in *Virippu* and 22.40 per cent in *Puncha* season. The productivity recorded during *Puncha* is the highest with 2719 kg per ha. The figures for *Virippu* and *Mundakan* are 2486 kg/ha and 2533 kg/ha. respectively (Economic Review, 2010).

Paddy cultivation in the state has been facing serious threats due to social, economic and political reasons. Paddy occupies 8.7 per cent of the gross cropped area. The net area under the crop in the state is reported as 2.34 lakh ha, which shows steady decline over the years (Fig.4.2.1.). Though there was notable area enhancement till the beginning of 1980's the area is under constant decline since then. The average annual decline in area under paddy during the Eighth Five Year Plan was around 22,000 ha, whereas it has come down to an average of 13,000 ha. during the Ninth Plan period. During Tenth Plan, it was 9,398 ha. During this period, the rate of decline was estimated at 3.23 per cent per annum (Parayil, 2010). Later in 2007- 08, decline in area was to the tune of 34,591 ha. from 2.64 lakh ha in 2006-07.

Trends in area, production and productivity of rice in *Kuttanad* and *Kole* from 1980-81 to 2007-08 is presented in table 4.2.1. During this period the annual compound decline rate was estimated at 3.06 per cent per annum. The trend in Alappuzha was at a lower level of 1.93 per cent, while in Thrissur, it was at a higher pace of 3.47 per cent. The geographic peculiarities and social dynamics in rice farming in Alappuzha perhaps limit its conversion or fallowing compared to

Fig.4.2.1 Trends in Area, Production and Productivity of Paddy in Kerala

Fig 4.2.1.1.Trend in Area of Paddy in Kerala

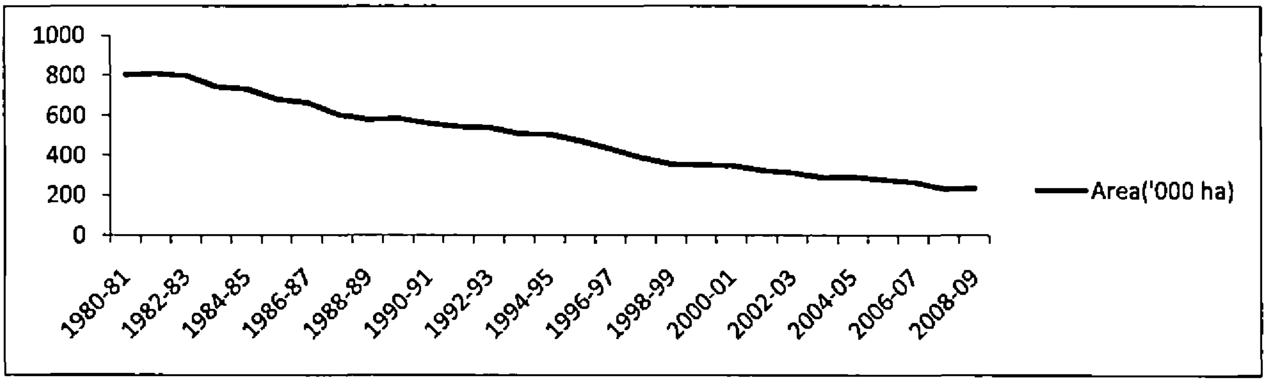


Fig 4.2.1.2.Trend in Production of Paddy in Kerala

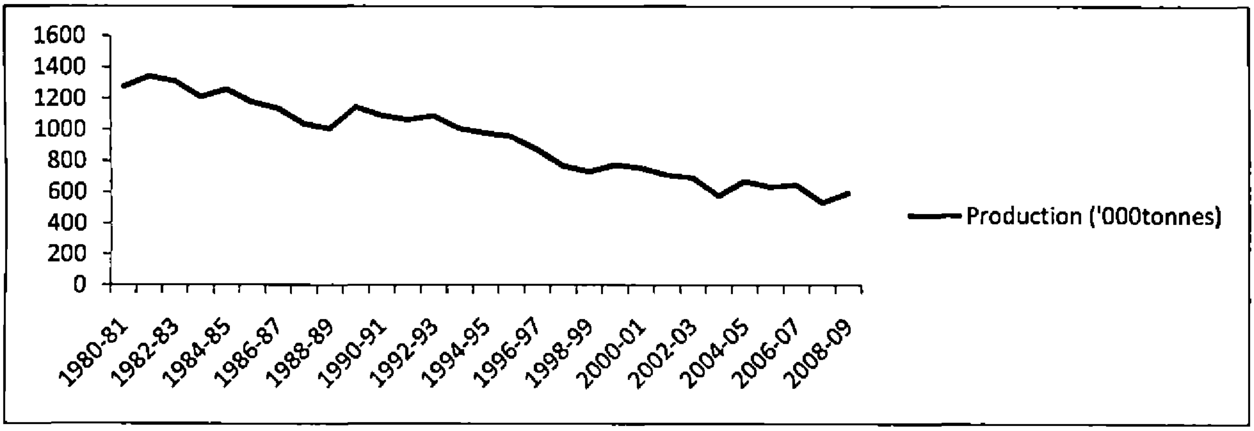
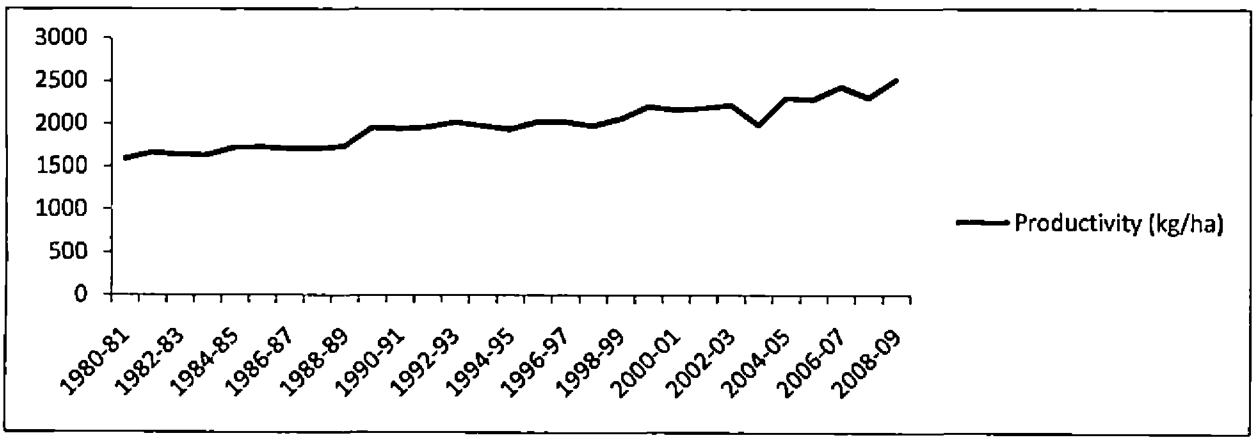


Fig 4.1.1.3.Trend in Productivity of Paddy in Kerala



Thrissur. But the coefficient of variation in area was lower in Thrissur and Alappuzha compared to the state level figure. However, recent legal and policy interventions has resulted in smoothening further decline in paddy area, and showed a slight increase to 2.34 lakh ha. in 2008-09. Further the decline was only a marginal 252 ha in 2009-10.

Table 4.2.1. Compound Annual Growth Rate and Coefficient of Variation of Area, Production and Productivity of Paddy in Kerala, *Kuttanad* and *Kole* (per cent per annum)

	Growth trends (1980-2008)			Coefficient of Variation (1980-2008)		
	Area	Production	Productivity	Area	Production	Productivity
Kerala	-3.06	-2.16	0.94	5.77	9.48	0.72
Alappuzha (*Kuttanad*)	-1.93	-0.70	1.03	0.64	1.16	0.80
Thrissur (*Kole*)	-3.47	-1.72	0.04	0.98	1.63	0.67

Kerala has always been food deficient since its formation in 1956. The gap between the requirement and production of rice has been showing an widening trend in the past decades .The deficit which was about 50 per cent in the 1960s, increased to more than 75 per cent in 1990s and to an alarming level of 85 per cent in 2007-2008. At present, the state produces only one-sixth of its total food grain requirement (Economic Review, 2010). For the rest, it depends on the Centre (Public Distribution System) and neighboring states like Tamil Nadu and Andhra Pradesh. During the period under study, production shows steady decline at the rate of 2.16 per cent. In the major growing centres, relievably, the decline is only at a rate of 0.70 per cent (Alappuzha) and 1.72 per cent (Thrissur). However the inter year variability in rice production is a high (9.48 per cent) in the state. But this was comparatively lower in the major growing centres.

Though the area and production statistics of rice economy in the state paints a dismal picture, the productivity trends show a positive growth performance, though modest (0.94 per cent)). In Alappuzha it is marginally higher at 1.03 per cent. But, Thrissur district figures (0.04 per cent) invite urgent policy attention. During the last decade, the productivity remained stagnant at 2.2 MT/ha till 2005-06, which slightly rose to 2.4 MT/ha. Technological, policy, legal and social support is warranted to address the paddy farming challenges in the state.

Among the host of reasons, the economic factors are often highlighted as most important factor affecting the poor performance in this sector. Radhakrishan as early as in 1983, observed that low profitability from paddy cultivation as having a depressing effect on paddy land prices and this contributing to the shifting of land away from cultivation thus resulting a net decrease in the area of paddy cultivation. The studies by Joseph (1982) estimated the gross returns of paddy as Rs. 5172. 82 in *Kuttanad,* with net returns of Rs. 1565.49. The benefit cost ratio was 1.43. Later, Mohandas (1994) attempted the economic analysis of paddy production in *Kuttanad* and *Kole.* He reported the benefit cost ratio of paddy at *Kuttanad* and *Kole* as 1.19 and 1.09 respectively. In both areas, returns to scale were found to be decreasing. *Kuttanad* recorded a high net return of Rs. 2450.82 and that of *Kole,* it was only Rs. 1054.56. Vijaya (1998) has conducted an economic analysis of paddy cum prawn culture in the *Pokkali* lands of Ernakulam district. When, paddy and prawn was integrated, the benefit cost ratio was found to increase to 1.6. Though the expenditure on the paddy and prawn was high, to an extent of Rs.11,144 to Rs.12,822, the net returns also were high to a tune of Rs. 15,051 to Rs 31,828. However, on relative terms, these economic indicators were less attractive.

Studies analyzing the resource use efficiency have shown inefficient levels of investment in most of the inputs in paddy cultivation. Most of the studies reported uneconomic level of use of human labour and reported it as the highest single item of expenditure. Muraleedharan (1982) has studied the resource use efficiency in rice cultivation in the low lying lands of Kerala. By employing the production function approach, he found that both at aggregate and individual farm levels, the inputs such as human labour, animal labour, fertilisers and manure are not efficiently used, in the sense that, the marginal return from these inputs were found to be less than the respective factor costs. He, therefore advised to curtail the use of these inputs to their optimum level. Parayil (2010) also attributes the rising labour cost as one of the important reason for supply constraint in rice output in Kerala. However, Devi (2011) made a detailed analysis of labour cost behavior in relation to returns from rice farming, and projects a different view. In this background, the existing system of paddy farming and economics in the study area is analysed in detail.

4.2.1. Paddy farming practices in the study area

Paddy cultivation in *Kuttanad* was traditionally known as *"Puncha"* cultivation as only the summer crop was cultivated in the region.Currently, the major rice growing season continues to be the *Puncha* season (November- December to February- March), though an additional crop is grown in some parts. The additional crop (May- June to Septmber-October), which coincide with the Virippu season in the state, is taken in nearly one third of the total paddy area in *Kuttanad.*The major paddy growing seasons and varieties are furnished in figure 4.2.1.1.

The paddy fields of *Kuttanad* are seperated into blocks of continuous area, separated by canals. Such blocks are known as "*Padasekharams*". A "*Padasekharam*" is a viable cultivable unit having an extent varying from 10 to 800 ha. These "*Padasekharams*" are used to be under 1 to 2 metre deep water during the South West monsoon period before the commencement of the cultivation season. At the time of cultivation, the water is bailed out with the help of a traditional device called " *Petti and Para*" or energized pumpsets. This is an axial flow pump with low head and high discharge. After completely draining out water, the outer bunds of the "*Padasekharams*" are strengthened and the fields, made ready for cultivation.

The fields are then ploughed, often in waist deep water. This help to stir up the soil and allow fresh water to percolate in to the soil. Ploughing would also help in removing acidity and other toxicants from the soil through the flush of water. The inner bunds, which are made to demarcate individual plots are strengthened and this operation is known as "*Varambu kuthal*" (in local language). Along with this, small channels are made, to facilitate irrigation and drainage.

Fields are then levelled and cleared of weeds and stubbles .It was a common practice to apply farmyard manure or green leaves or both. Now-a-days, it is not common because of the high material and transportation cost. After levelling, fresh water is let into the field. Simultaneously, seeds soaked for about 8 to 12 hours and drained to induce sprouting.

The main varieties of paddy in *Kuttanad* were *Kochuvithu, Kulappala* and *Vykkatharyan* in the earlier times. Since they were non fertilizer responsive, photo sensitive and low yielding, they were replaced by the varieties like *Uma, Bhadra, Asha* and *Makom* (varieties released by Kerala

Fig4.2.1.1 Paddy seasons in *Kuttanad*

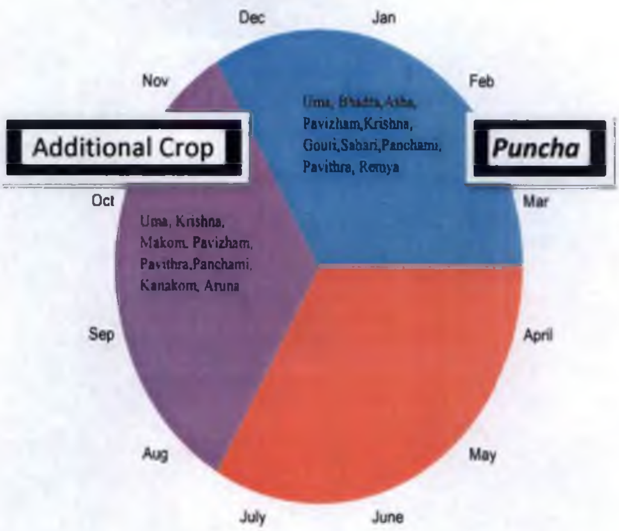
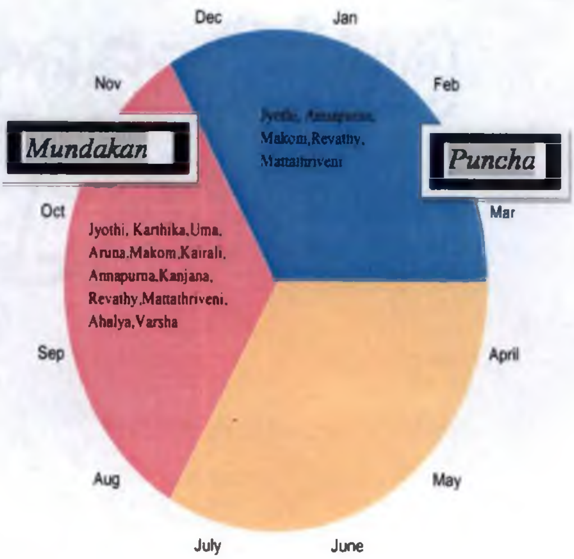


Fig. 4.2.1.2. Paddy seasons in *Kole*



Agricultural University). Sprouted seeds are broadcasted in the field in ankle- deep water. The seed rate recommended by Kerala Agricultural university is 100 kg per hectare , but cultivators in general adopt a higher seed rate of 100-125 kg per hectare on the presumption that thick stand reduce weed growth and compensate the losses due to bird picking etc. Three to four days after sowing, the fields are completely drained and kept moist for about a week. Transplanting is also done in certain parts.

After gap filling (25- 30 days after sowing) first weeding as well as top dressing is carried out. In the areas where p^H of the soil is below 5.5, liming is essential. In areas where p^H ranges from 5.5-6.5, liming improves the soil quality. Calcium carbonate, lime or dolomite are used based on soil testing results.

Fertilisers act as the major source of nutrients for paddy in Kuttanad. The KAU fertilizer recommendation of NPK @ 90:45:45 kg/ha or its slightly higher dose is applied by most of the farmers which is applied in 2-3 doses. The first application comprising of half the quantity of Phosphorus, one third dose of Nitrogen and Potassium is done 10-20 days after sowing. The second dose of fertilizer (half P, one third N and K) is given 5-10 days after gap filling. The remaining one third of N and K is top dressed at the time of panicle initiation (60-65 DAS). The fields are drained before fertilizer application and kept moist for about two days.

The pesticide use in paddy farming in *Kuttanad* was reported to be very high and the application practice as unscientific (Devi, 2007) Owing to the general awareness and policy change, a regular pattern of plant protection is not seen adopted in *Kuttanad* now. Need based plant protection operations are being followed by farmers. However, the high yielding varieties necessitate the intensive use of plant protection chemicals.

The paddy fields require an optimum water level for the growth of the seedlings. Water is let in and drained out occasionally (every 10- 15 days) so as to maintain a continuous water level of about 5 cm in the field. Field is completely drained about 10 days before harvest.

In older days, harvesting was done manually. The harvested earheads of paddy are cut and tied to bundles ("*Katta*"). Later, threshing and winnowing are done. The cleaned grains are often sold at threshing floor. The wages for harvesting is paid in kind as18-20 per cent of the total grain harvested and threshed by a labourer (known as "*Padham*" or "*Theerpu*") (Joseph, 1982 and Mohandas, 1994). However, all these operations are mostly mechanized now.

Paddy seasons and varieties in Kole lands are presented in figure 4.2.1.2. In *Kole* lands, since water management is a major problem, Virippu crop is confined to only the higher areas. Varieties *like Jyothi, Pavizham, Kanakom, Aswathy, Makom, Sabari, and Bharathy* are usually cultivated and sowing is done along with the onset of South West monsoon (June). These varieties are tolerant to slight flood condition. The crop is harvested in September - October. Mundakan crop is taken in medium elevation fields, where the flood water resides by August. *Kadumkrishi* in *Kole* lands coincide with Mundakan in normal lands, but usually start by September. However, in order to undertake *Kadumkrishi*, the Kole lands are to be protected by bunds. When the flood water in the *Kole* fields starts subsiding by the end of South West monsoon season (August– September), water is drained out. Dewatering is carried out using "*Petti and Para*", which is an indigenous pumping device for dewatering. After this, bunds around the fields or *Padavus* are raised and strengthened by means of locally available materials and laterite soils to a height of 1 to 1.5 m above the field level. Crop is directly sown or transplanted when water is around 10 to 15 cm. In *Kadumkrishi* water management is very important as it requires continuous pumping out of water .Towards later stages of crop growth irrigation is to be given.

Puncha is the crop raised over the entire *Kole* area (nearly 15,000ha). The season starts in November- December and completed in March- April. Wherever bunds have not been made for *Kadumkrishi*, temporary earthern bunds are put up around the fields or *Padasekharams*. For *puncha* water requirements in the early stages of crop are met from summer flow in the rivers and the storage canals and in later stages they depend on irrigation projects. Since late 1980s, the North *Kole* is divided into three zones for puncha cultivation. Usually in the first and second zones only puncha is taken and in the third zone an additional crop or *Kadumkrishi* is also raised. In the zonal system of cultivation, water management is very efficient. Under this system, dewatering is carried out zone wise. Water pumped out from one zone is collected in other zones and is used as irrigation water as and when required. Dates are specified in advance for starting and ending dewatering in each zone by the District Administration in consultation with the *Padasekharam* Committees who carry out pumping operations.

The normal practice is to start dewatering by second week of November and complete sowing by first week of December in zone 1. Water pumped out of zone 1 is collected in zone 2 which in turn is used as irrigation water for zone 3. Zone 3 would be under *mundakan* crop by then. The *mundakan* crop would have started by third week of September and lasts until end of December. Once the harvest is completed by December end, water from zone 2 is pumped out and stored in the zone 3. Zone 3 would be under water for almost one month after which the fields will be prepared for *puncha* crop. The water which is now pumped out of zone 3 and stored in the *Kole* canals for summer irrigation. Cooperation and collective action of farmers are very important in this zonal system. Additional irrigation water requirements are met from Peechi and Chimmony dams. The farmers consider the zonal system of cultivation as the most practical and convenient way to undertake cultivation in the *Kole* fields by managing flood water in an efficient manner.

The conventional varieties in *Kole* farming were *Ponnaryan, Chembavu, Kunjathekkera* when there was only one crop season. Now the major varieties in the area are *Jyothi, Karthika, Uma, Aruna, Makom, Annapurna, Kanchana, Kairaly, Revathy, Mattathriveni, Ahalya, Varsha* etc. *(Virippu), Annapurna, mattathriveni, Swarnaprabha, Karthika, Aruna, Makom, Kanchana, Kairali, Aswathy, Jaya, Pavizham, Remya Aiswarya, Jyothi,* and *Uma (Mundakan)* and *Jyothi, Annapurna, Makom, Revathy* and *Mattathriveni (Puncha).* All these varieties are released by Kerala Agricultural University. The farmers prefer *'Jyothi'* because it fetches better price and is relatively superior in taste. For past 20 years *'Jyothi'* is cultivated in *Kole* lands. The management practices and harvesting of the crop in Kole is almost similar to Kuttanad region.

4.2.2. Economics of Paddy Cultivation

The data on item wise cost of cultivation for the crop for Kerala, Alappuzha and Thrissur was compiled from the records of Department of Economics and Statistics. The data gathered from sample farmers in the study area is also presented. Analysing the data gathered, the economics of paddy farming in Kerala, Alappuzha and Thrissur is presented in table 4.2.2.1. The total paid out cost of cultivation (Cost A_1) was estimated as Rs 20,980 per ha for the state as a whole, which was up by 22.59 per cent in Alappuzha and 13.51 per cent in Thrissur. While the estimates based on farmer responses closely match with the Department of Economics and Statistics estimates for Alappuzha, there is a sizeable difference of nearly Rs.5,000 per ha between the Department of Economics and Statistics estimate for Thrissur and data gathered from farmers/ society.

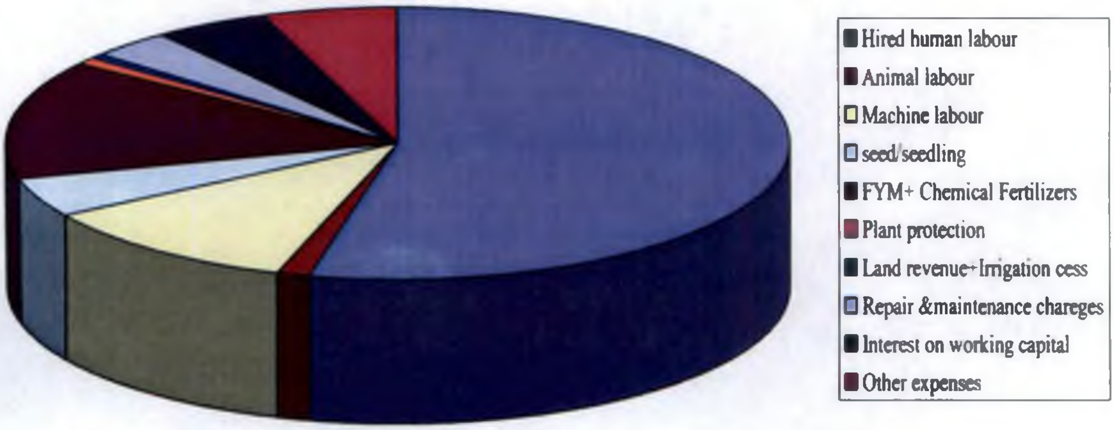
The human labour still constitute the major share of total cost in paddy farming (Fig 4.2.2.1). It amounted to Rs. 11,234 per ha (53.5 per cent) in the state, with a variability of Rs. 12,367 in Thrissur and 13,356 in Alappuzha. Together with machine and bullock labour, the total cost of labour was reported as Rs.13,889 in Kerala, Rs.17,149 in Alappuzha and Rs.15,879 in Thrissur. Devi (2011) also highlights the labour intensive nature of paddy farming and the average labour use was estimated at 61.86 mandays/ha for autumn, 67.67 mandays/ha for winter and 73.09 mandays/ha for summer seasons .Thus paddy farming alone is creating 203.63 mandays of employment per hectare per year in the state. This amounts to 466.31 lakh mandays, at the present level of 2.29 lakh ha of area under cultivation. The labour use in summer is the highest, though there is not much difference in labour use between seasons.

Manures and fertilisers costed Rs.2,962 (in Kerala).The expenditure reported by the farmers were higher than the estimates of Directorate of Economics and Statistics. Proportionately, this amounted to 14 per cent of total cost.

The average yield realized by the farmers in Kerala was 2.4 tonnes/ ha as against the potential yield of 3.32 t/ha (for *Uma* at Rice Research Station, Mancompu) and the national figure of 3.21 t/ha. Though Department of Economics and Statistics estimates showed yields of 2.4t/ha, the farmers in Kole area reported higher yield realization. Thus the Gross Returns amounted to an average of Rs.35,462 for the state, with a BC ratio of 1.69. The corresponding figures for Alappuzha are Rs 34,565 and that for Thrissur Rs. 35,567. As per primary data, the Gross Returns in *Kuttanad* was Rs.34,500 with BC ratio of 1.32 and in *Kole,* it was Rs.44,700 with BC ratio of 1.56. Generally, the average yield of paddy in Alappuzha (*Kuttanad*) and Thrissur (*Kole*) are reported as almost on par at 3 t/ha. The low yield of paddy at Alappuzha (*Kuttanad*) in 2007-08 may be due to the heavy summer rainfall, which caused severe crop loss to the farmers.

Table.4.1.4.1. Input wise costs and return of Paddy Cultivation in Kerala (2007-08)						
Region	Kerala	Alappuzha	Thrissur	*Kuttanad*	*Kole* (Farmer data)	*Kole* (Cooperative society)
Hired human labour	11,234	13,356	12,367	13,604	15,000	14,692
Animal labour	313	418	387	426	400	460
Machine labour	2342	3375	3125	3438	4000	3713
seed/seedling	967	1338	1239	1363	1500	1472
FYM+ Chemical Fertilizers	2962	3794	3513	3864	4000	4173
Plant protection	217	321	297	327	400	353
Land revenue + Irrigation cess	93	149	138	44	45	44
Repair & maintenance chareges	680	555	514	565	600	611
Interest on working capital	985	1248	1156	1272	1300	1373
Other expenses	1187	1164	1078	1186	1300	1281
COST A_1	20,980	25,719	23,814	26,088	28,545	28,171
Avg.Yield (t/ha.)	2.4	2.4	2.43	2.4	3	2.8
Gross Returns/ha	35,462	34,565	35,567	34,500	44,700	41,720
Net Returns	14,482	8846	11,753	8412	16,155	13,549
BC Ratio	1.69	1.34	1.49	1.32	1.56	1.48

Fig. 4.2.2.1.Distribution of Total Cost in Paddy Farming (2007-08)



The Farm Business Income (Gross returns-Cost A_1) from the crop was Rs.14,482 in Kerala and Rs.8,412 in Alappuzha and Rs.16,155 in Thrissur. With an average holding size of 1.93 ha. in *Kuttanad*, the Farm Business Income (FBI) was only Rs.16,235 and that in *Kole* lands (average holding size 1.84 ha) was Rs.29,725. At state level, this amounted to Rs.14,482.

As per National Sample Survey Organisation, Kerala leads in living standards, with a Monthly Per capita Consumption Expenditure (MPCE) for rural Kerala at Rs.1,835. For the average family (of size 5.7 in Alappuzha and 5.75 in Thrissur) the total household consumption expenditure per month amounts to Rs.10,551. In Alappuzha, it amounts to Rs. 10,460. It may be remembered that, for 82 per cent of farmers in *Kuttanad*, the major source of income is from paddy farming/agriculture . The average returns from paddy farming for a household thus, could meet only household consumption expenditure for a period of 1.5 months.

In *Kole* areas, the monthly household consumption expenditure was estimated at Rs.10551. The household income from paddy farming was enough to meet 2.8 months expenditure which was better compared to *Kuttanad* situation. This situation makes the returns from rice framing very relevant in the context of livelihood of the farmers in these areas. In the event of risks in production /income the farmers naturally have the tendency to find alternate sources of income.

Over the years (1980-81 to 2007-08), the increase in total cost of cultivation (current price) is gradual (Fig 4.2.2.2), from Rs.2,733 in 1980-81 to Rs.20,980 in 2007-08 (Kerala). When the estimates are analysed in constant terms, deflating with the index of price paid by the farmers, the trend shows a different pattern (Fig. 4.2.2.3). The pattern is similar for the three data sets (Kerala, Alappuzha and Thrissur) though they differ in magnitude. The trend in Gross Returns during this period is presented in fig 4.2.2.4 and fig 4.2.2.5. At current prices, though the trend is positive, it is not so, when the returns are considered in constant terms. The Gross Returns shows stagnant/ decreasing tendency over years. The price parity ratios for the farmers in Kerala, also shows an adverse terms of trade for farmers in Kerala (Economic Review, 2010).

Moreover, though paddy farming is reported as economically viable, the relative economic advantage compared to other technical options are rather very low. For instance, the net returns from banana and vegetables are much higher than rice farming (Saijyothi, 2005 and Divya, 2007), not to mention the other commercial, non agricultural options. Along with this, the demographic and development pressures are compelling for large scale conversion of paddy lands for non agricultural purposes as well.

The state government, through major interventions in legal (Kerala Paddy Land- Wet Land Conservation Act, 2008) and policy (food security project) sphere, have introduced several programmes for conservation of paddy lands and for improving paddy production. Paddy development activities in the State were carried through State schemes and Centrally sponsored schemes. The ultimate objective of paddy development programme during the Eleventh Plan period to sustain rice cultivation in 4.4 lakh ha and to augment the average productivity to more than 2.8 tonnes per ha. Revitalisation of group farming samithies in predominant paddy growing areas, assistance to paddy development agencies and assistance to seed development agencies were continued under State plan for attaining the targeted level of paddy production and productivity. Apart from this, 3799 ha of fallow land has been brought under cultivation. A special scheme as part of food security project for 36 crores was also launched in 2009-10 and consolidated in 2010-11 for the development of paddy in the state. In order to increase food production in the state, a major food security project was launched in 2008-09 covering paddy, milk and egg. As part of the project, regional subprojects were launched with additional incentives, interest free loans, project based support for fallow land cultivation and a package of support measures. The procurement price was also enhanced to Rs.13 per Kg. Additional support was also provided for upland paddy cultivation in potential areas for the first time in Kerala in 2009-10.Thus, policy support through institutional, technological and political backing is being introduced for the purpose (Economic Review, 2010).

Considering the ecological significance of paddy fields, the conversion of paddy lands for other purposes was curtailed from 2009-10 consequent to the Kerala Paddy Land – Wet Land Conservation Act, 2008.

Fig 4.1.4.2.Cost of cultivation of Paddy in current price (1980-81 to 2007-08)

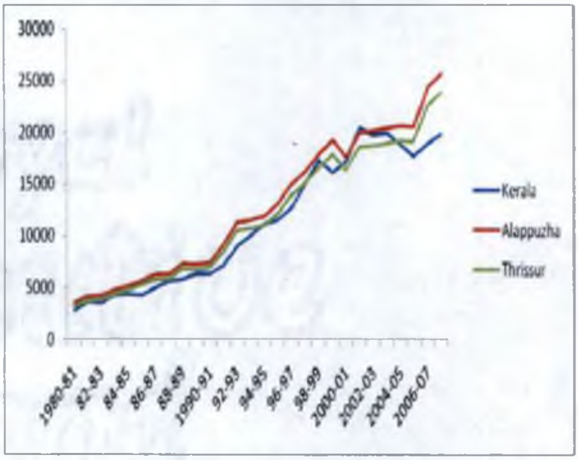


Fig. 4.1.4.3. Cost of cultivation of Paddy in deflated (constant price) (1980-81 to 2007-08)

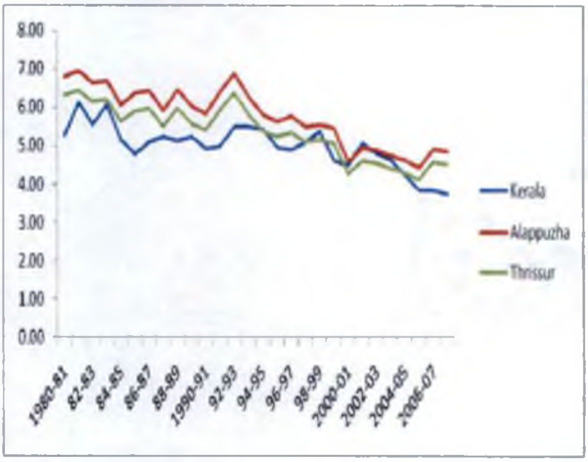


Fig. 4.1.4.4. Gross Returns of Paddy in current price (1980-81 to 2007-08)

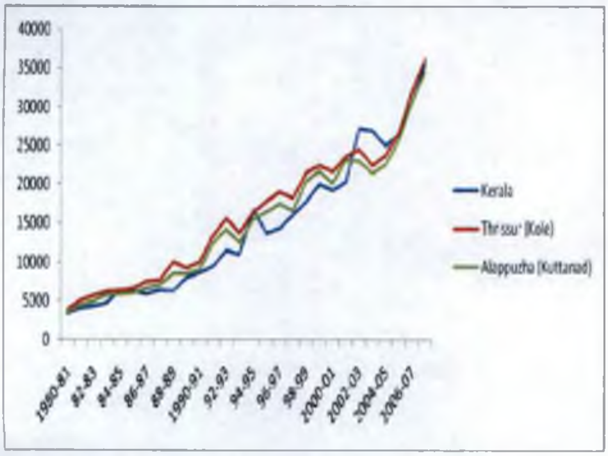
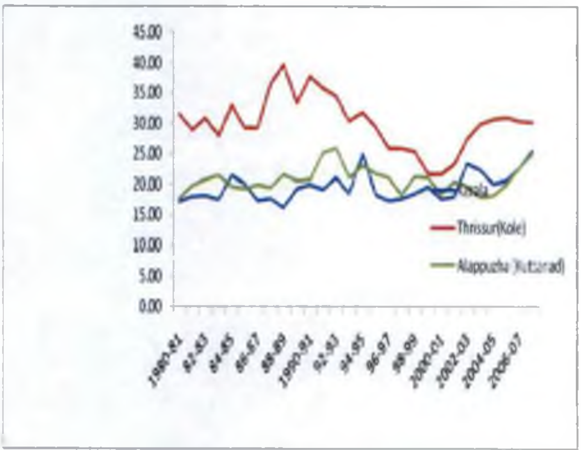


Fig 4.1.4.5. Gross Returns of Paddy in deflated (constant) price (1980-81 to 2007-08)



4.2.3. Climate and Paddy Production

Along with the socio economic and management aspects, weather factors also exert profound influence on paddy output. Climatic elements such as temperature, precipitation, radiation, humidity and wind speed are found to have a profound influence on the growth, development and yield of paddy crop. There are studies reported from across the globe quantifying the impacts of these factors in the background of climate change trends (Lonergan *et al.*,1991;Brklaich and Smit, 1992; Wang *et al.*,1992; Seino,1993; Brklaich *et al.* ,1994; Rosenzweig and Parry,1994; Erda, 1996 ; Iglesias *et al.*,1996; Reilly *et al.*, 1996; Ali,1996, 1999; Amien, 1996, 1999; Wijeratne, 1996; Pilifosova *et al.*, 1997; Kumar and Parikh , 1998; Ramakrishnan ,1998; Alderwish and Mohamed 1999; Booth *et al.*, 1999; Jose and Cruz, 1999; Luo *et al.*,1999; Siddiqui *et al.*, 1999; Aiwen, 2000; Murdiyarso ,2000; Saseendran *et al.*, 2000; Mirza, 2002, 2003; Alkolibi, 2002; Yu *et al.*, 2004; Rao *et al.*, 2008 and Lobell *et al.*, 2011)

In Kerala the study conducted by Saseendran *et al.*,(2000), made projection on the effect of changes in weather variables on paddy output. Paddy maturity period is projected to shorten by eight per cent and yield increase by 12 per cent. When temperature elevations only are taken into consideration, the Crop Simulations show a decrease of eight per cent in crop maturity period and six per cent in yield. This showed that the increase in yield due to fertilisation effect of elevated CO_2 and increased rainfall as projected in the climate change scenario, nearly, makes up for the negative impact on paddy yield due to temperature rise. The sensitivity experiments of the paddy model to CO_2 concentration changes indicated that, over the state, an increase in CO_2 concentration leads to yield increase, due to its fertilisation effect and enhanced the water use efficiency. The temperature sensitivity experiments have shown that for a positive change in temperature up to 5 and17^{0}C, there is a continuous decline in the yield. For every one degree increment, the decline in yield is about six per cent. In another experiment conducted by the same authors, it was observed that the physiological effect of ambient CO_2 at 425 ppm concentration compensated for the yield losses due to increase in temperature up to 2 and17^{0}C. Rainfall sensitivity experiments have shown that increase in paddy yield due to increase in rainfall above the observed values were near exponential. But decrease in rainfall results in yield loss at a constant rate of about eight per cent per 2 mm/day, up to about 16 mm/day.

The changes in weather pattern over the state is often noticed as the changes in onset of monsoon rainfall, its intensity and spread (Rao *et al.*, 2008). During 2010, the South West monsoon onset over Kerala was on 31st May 2010, one day earlier than its normal date of 1st June and the actual rainfall received in Kerala during the season (1st June 2010 to 30th September 2010) was 1932 mm as against the normal rainfall of 2142.9 mm. which was normal. All the 12 districts in the state received normal rainfall while two districts Thiruvananthapuram and Wayanad received deficient rainfall of -27 per cent and -52 per cent respectively (Economic Review, 2010).

During the North East Monsoon season 2010, the state received 825.7 mm of rainfall as against 498.5 mm which was in excess of 66 per cent from the normal. All the 12 districts in Kerala received excess rainfall during this season. The deviation was highest in Kannur district (111 per cent) followed by the Thrissur district (107 per cent). The Idukki and Wayanad districts however received normal rainfall. Kerala received 359.6 mm pre monsoon rainfall (from 1st March to 31st May 2010) which was normal. Eight districts in the state (Alappuzha, Ernakulam, Kollam, Kottayam, Kozhikkode, Pathanamthitta, Thiruvananthapuram and Wayanad) received normal rainfall while five districts (Kannur, Idukki, Malappuram, Palakkad and Thrissur) received deficient rainfall. Kasaragod district received scanty rainfall during the season with a departure of -62 per cent from the normal (Economic Review, 2010).

Fig. 4.2.3.1, Fig 4.2.3.2 and Fig 4.2.3.3 and table 4.2.3.1 represents the trend in minimum temperature, maximum temperature and rainfall over the years in the state as well as in the study areas (*Kuttanad* and *Kole*) during 1980-2008. Though, no definite pattern can be arrived at from the figures, Rao *et al.*, (2008) has concluded that the Kerala state has moved from wetness to dryness since last fifty years, and it is being shifted from "B_4 Humid to B_3 Humid climatic type".

Table.4.2.3.1 furnishes the pattern of change in the weather parameters during the study period. The maximum temperature in the state showed an annual rate of increase of 0.02 per cent over a short span of 28 years and it was a high 0.12 per cent in Alappuzha (*Kuttanad*). In *Kole* region, however, there was a marginal decline. The variability in maximum temperature was not very high, and was almost on par in *Kole* and *Kuttanad* region, and showed lower variability than that of the state level data.

The minimum temperature exhibited a lowering tendency for the state as a whole, though it was not so in the two study regions. Excepting *Kuttanad*, rainfall was decreasing in the state and Thrissur. The heavy summer showers in *Kuttanad* must have been the reason for a positive figure for this region. The variability in rainfall was a high 14.11 per cent in Kerala, 13.54 per cent in *Kole* and 6.93 per cent in *Kuttanad.*

Table. 4.2.3.1. Growth trends and Coefficient of Variation of Weather parameters (1980-2008)

	Weather parameters	Kerala	*Kuttanad*	*Kole*
Compound Annual Growth Rate (%)	Maximum temperature	0.02	0.12	-0.07
	Minimum temperature	-0.03	0.05	0.09
	Rainfall	-0.09	0.86	-0.67
Coefficient of Variation (%)	Maximum temperature	1.56	1.41	1.41
	Minimum temperature	2.39	1.19	1.19
	Rainfall	14.11	6.96	13.54
Mean	Maximum temperature (^{0}C)	34.3	35.1	34.8
	Minimum temperature (^{0}C)	29.8	27.9	28.6
	Rainfall (cm)	311	83.48	78.61

Rainfall and maximum temperature are the two major weather parameters, which are generally reported to have an impact on the paddy production in tropical setups (Saseendran *et al.,* 2000). The interrelationship of these variables on production of paddy in presented in Fig 4.2.3.4, 4.2.3.5, 4.2.3.6, 4.2.3.7, 4.2.3.8 and 4.2.3.9.

This result underlines the importance of location specific studies as the behavior of weather parameters shows wide variations in magnitude and direction, across the locations.

The maximum temperature and rainfall at cropping seasons i.e.(October – November to February- March) and paddy production trends in *Kuttanad* and *Kole* is presented in Fig 4.2.3.10, 4.2.3.11, 4.2.3.12 and 4.2.3.13. It may be pointed out that, the influence of these parameters are more decided by the critical periods of growth of the crop. The stage of crop growth and corresponding weather parameters are to be studied in that case.

Fig 4.2.3.1. Average Minimum Temperature (^{0}C) in Kerala (1980-2009)

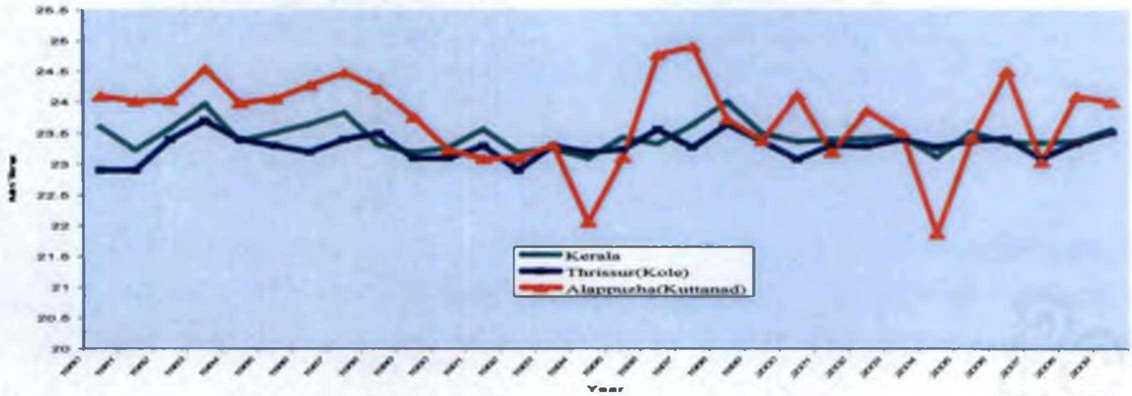


Fig. 4.2.3.2. Average Maximum Temperature (^{0}C) in Kerala (1980-2009)

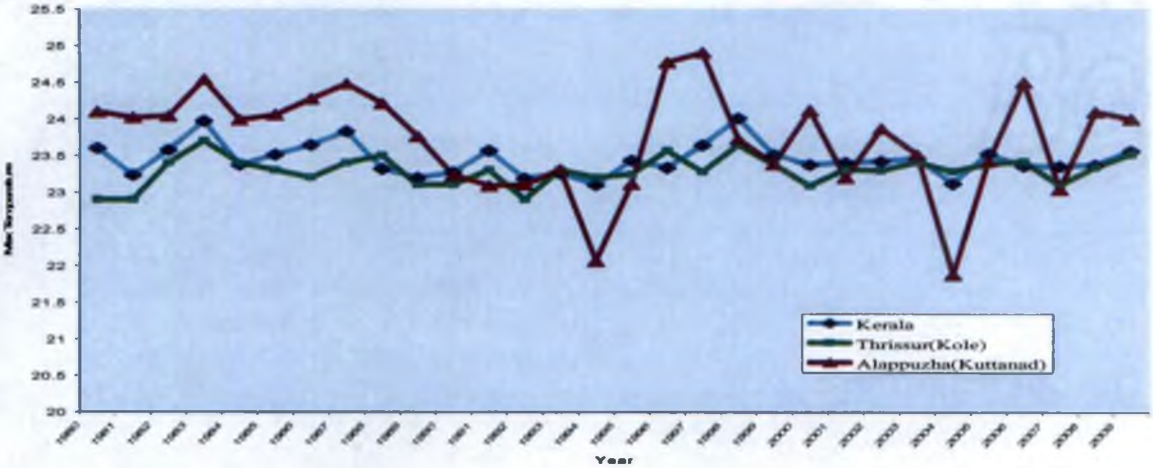


Fig. 4.2.3.3. Average in Rainfall (cm) in Kerala (1980-2009)

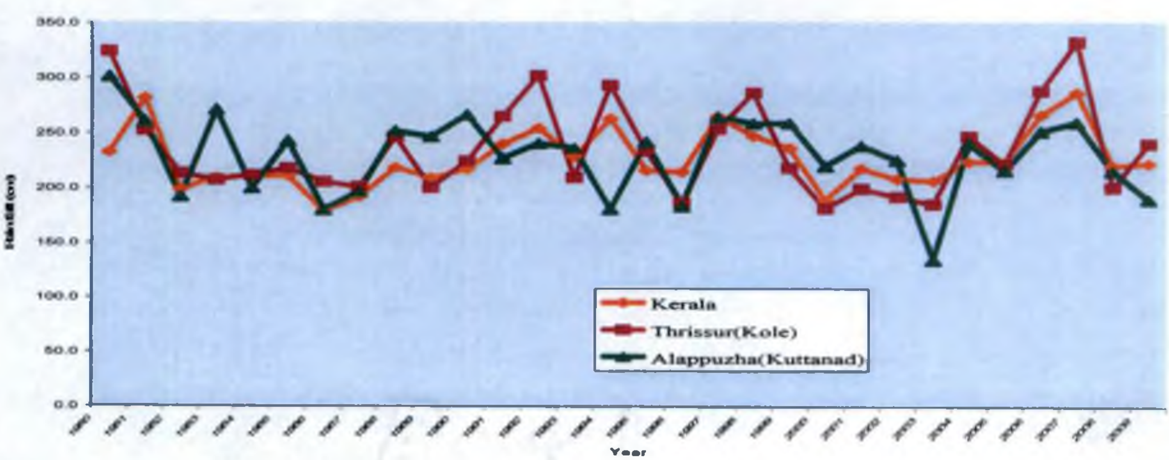


Fig.4.2.3.4 Maximum Temperature and Production Trends in Paddy in Kerala

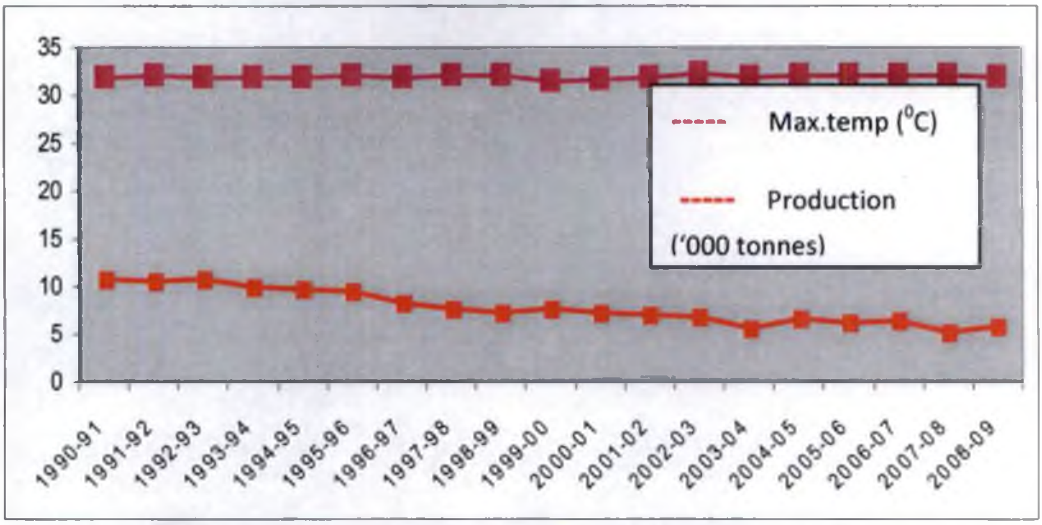


Fig. 4.2.3.5 Maximum Temperature and Production Trends in Paddy in Alappuzha

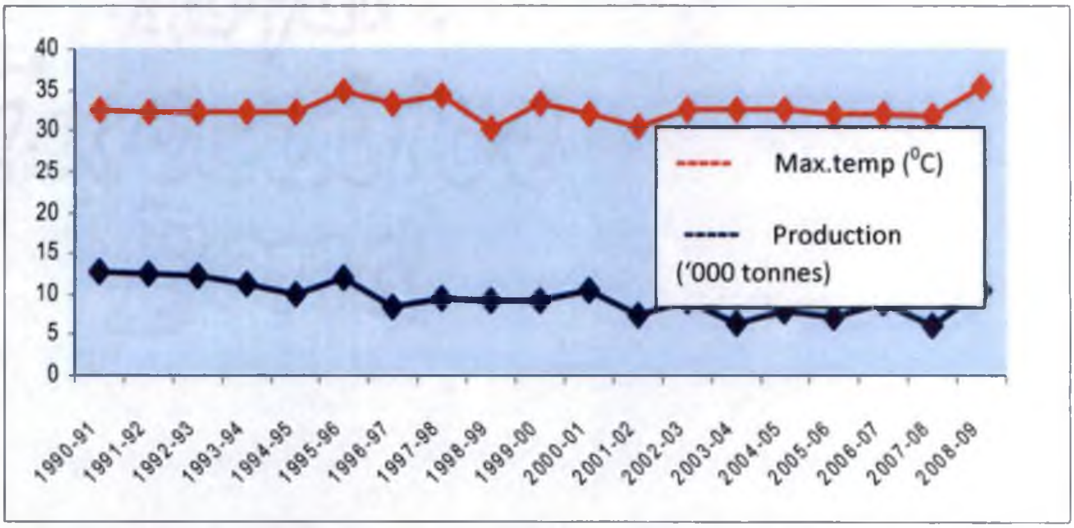


Fig. 4.2.3.6 Maximum Temperature and Production Trends in Paddy in Thrissur

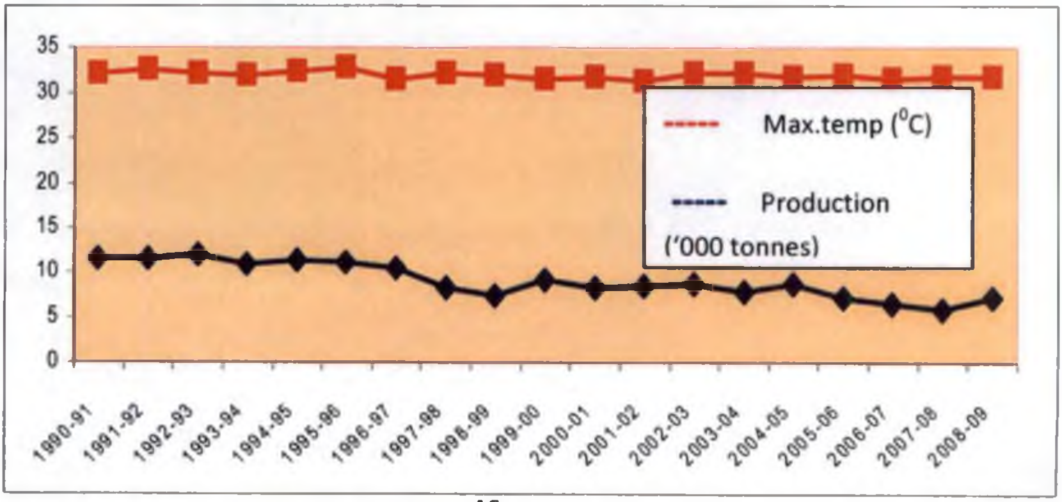


Fig.4.2.3.7. Rainfall and Production Trends of Paddy in Kerala

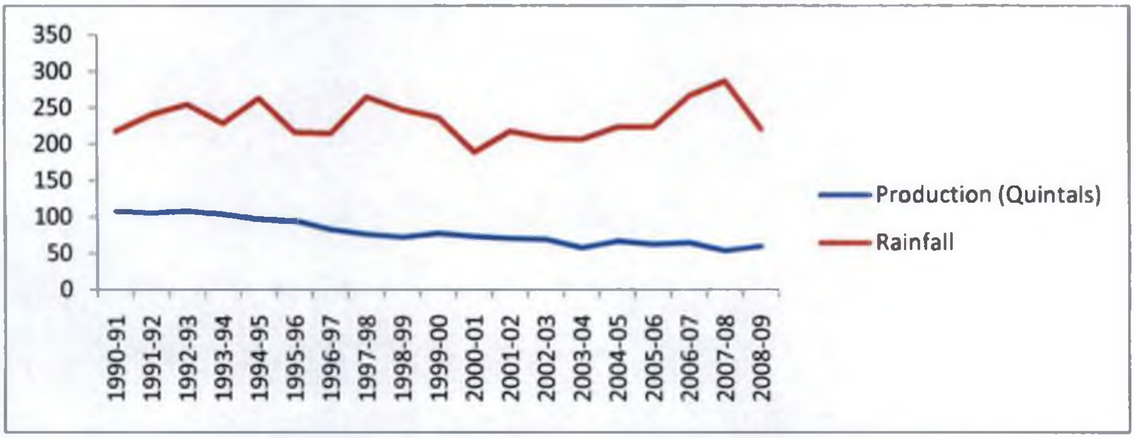


Fig.4.2.3.8. Rainfall and Production Trends of Paddy in Alappuzha

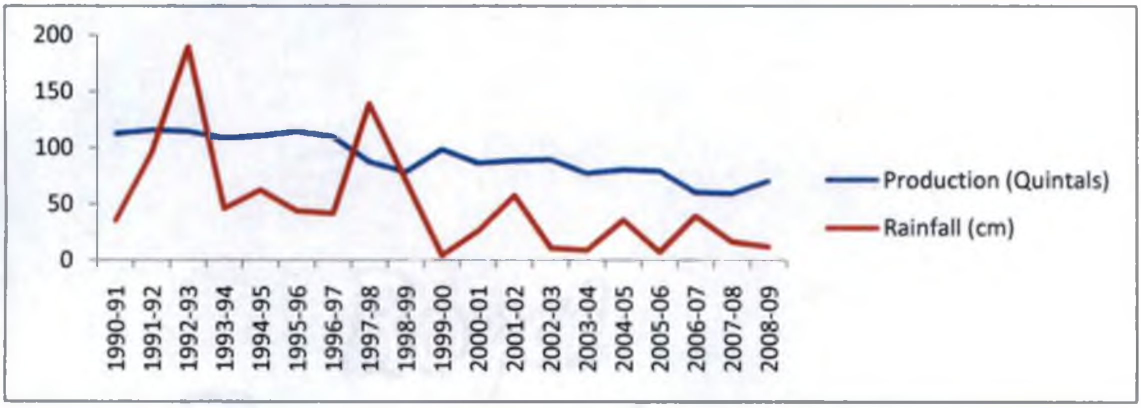


Fig.4.1.3.9. Rainfall and Production Trends of Paddy in Thrissur

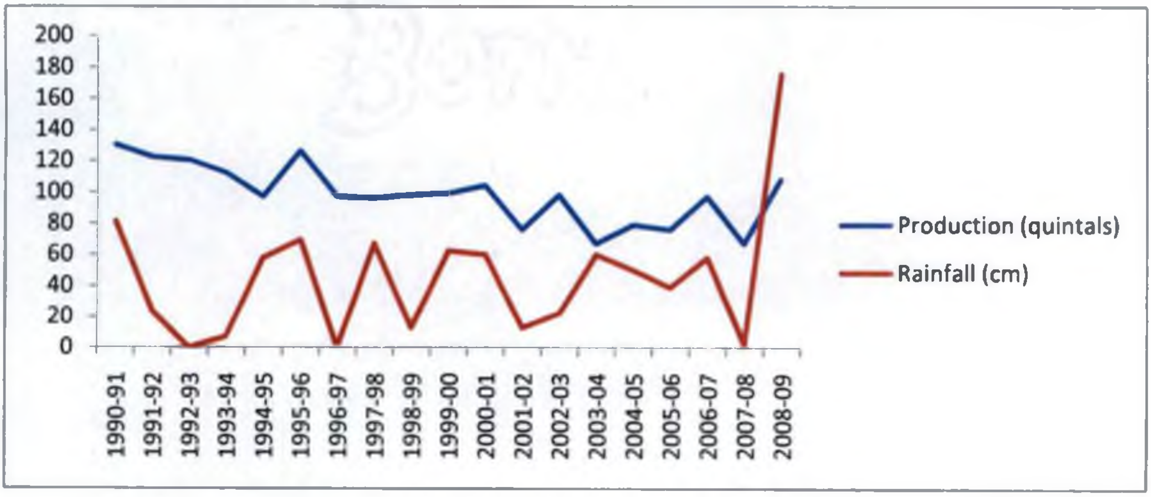


Fig.4.2.3.10 Maximum Temperature at Cropping Season and Production Trends of Paddy in *Kuttanad* (Alappuzha)

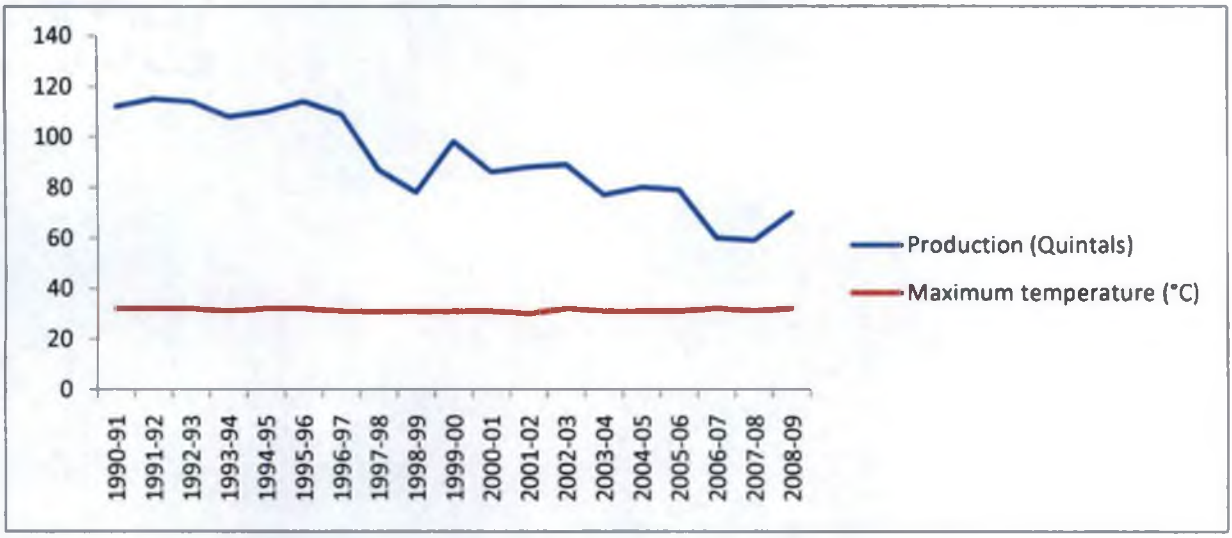


Fig.4.2.3.11. Maximum Temperature at Cropping Season and Production Trends of Paddy in *Kole* (Thrissur)

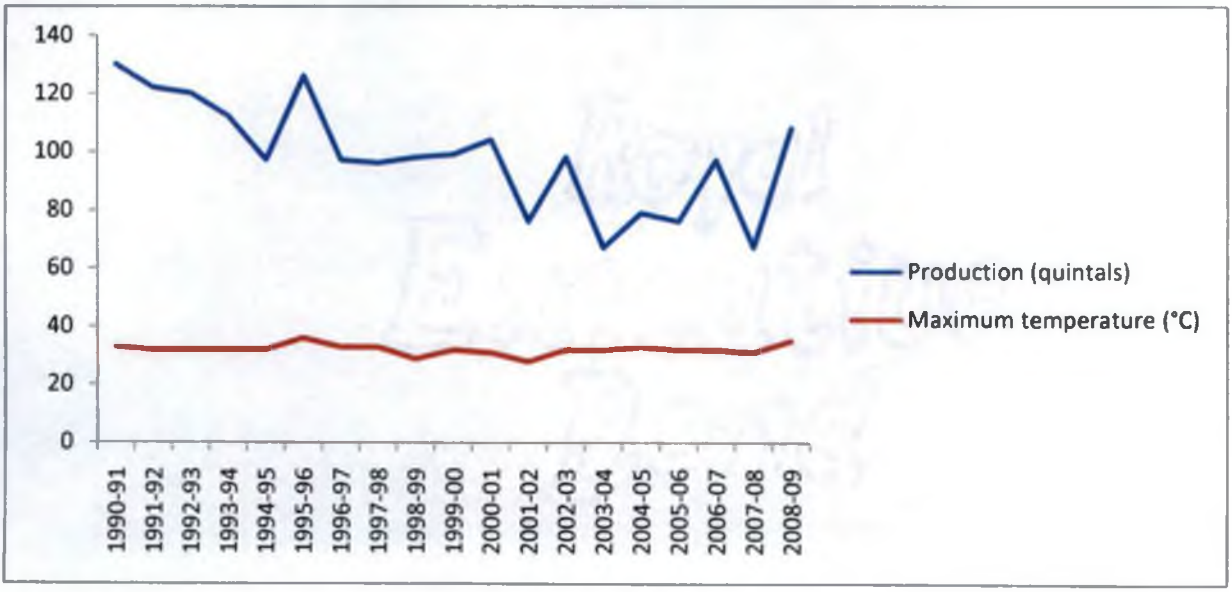


Fig.4.2.3.12. Rainfall at Cropping Season and Production Trends of Paddy in *Kuttanad* (Alappuzha)

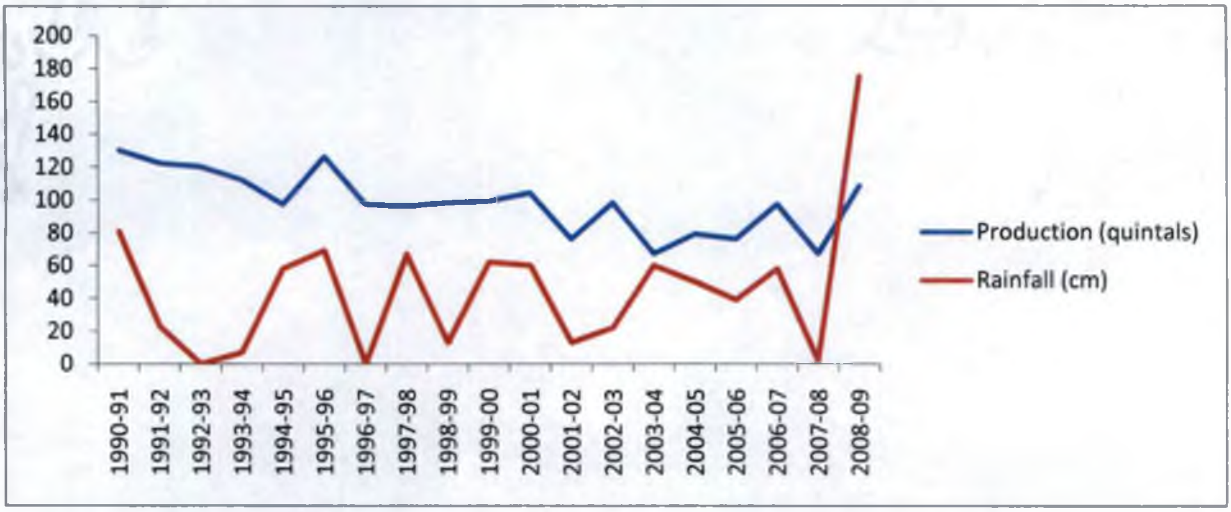
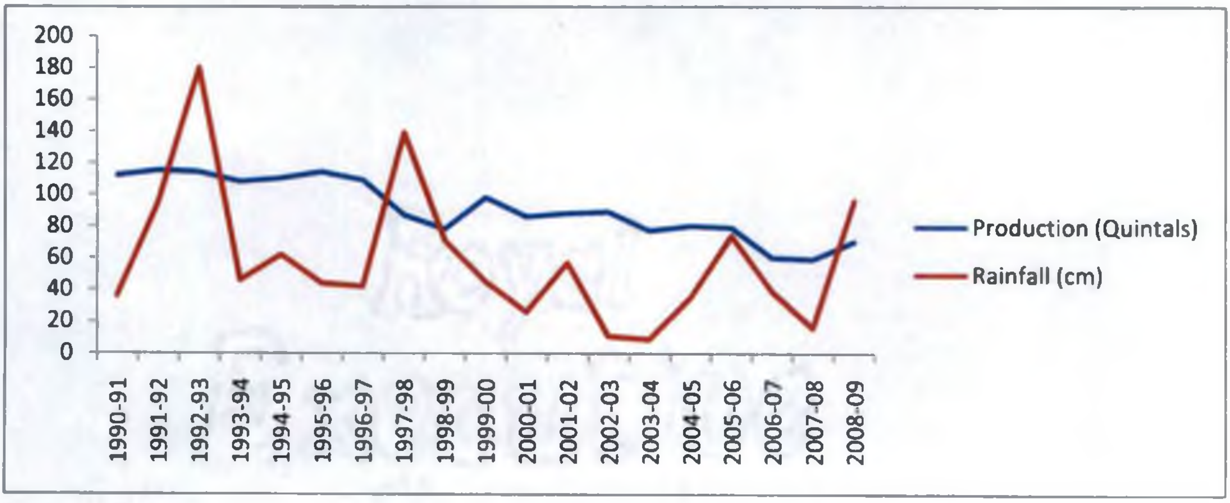


Fig.4.2.3.13 Rainfall at Cropping Season and Production Trends of Paddy in *Kole* (Thrissur)



4.2.4. Economic Impact of Climate Change on Farm Business Income from Paddy

There have been several global attempts on quantifying the impact of climate change on major crops. In 1989, Environmental Protection Agency (EPA), ERL-C, and International Rice Research Institute (IRRI) have initiated a comprehensive project to identify the relationship between climate change and paddy production in Asia, mainly depending on Crop Simulation models. It was predicted that paddy production in India would increase in the main season, offsetting the decline in the second season, thus affecting a positive effect on output. In another study, the relationship between Indian summer rainfall and food grain production is found to be closely related (Selvaraju, 2003). However, Mall *et al.*(2006), made a comprehensive review of studies based on simulation techniques and concluded the effect as uncertain. It may vary quantitatively and qualitatively with crop, level of agronomic management, region and season, he concluded. For instance, the rainfall fluctuations in India have been random over a century with no systematic change detectable in summer monsoon season (Mall *et al.,* 2006).These observations underlines the need for region specific micro level studies to assess the impact of climate change on agriculture.

The economic impact of climate change include the direct loss due o reduced production, yield effects due to weather extremes, loss due to damages to life and property. For example, the unexpected monsoon break in 2002 in India had resulted in a seasonal rainfall deficit of 19% and caused profound loss in agricultural output with a three percent drop in India's GDP (Challinor, 2005). Kumar (2009) has projected a decline in net revenue of agriculture by 21.3 per cent of the net revenue in 1990, for an increase of temperature by 2^0 C and rainfallby 7 per cent. If the temperature and rainfall increase is by 3.5^0C and 14 per cent respectively, the net revenue of agriculture would decrease by 85.3 per cent .

In this study, the multiple linear regression model was fitted with the panel data separately for *Kuttanad* and *Kole* areas. The descriptive statistics is furnished in Appendix II and III. The model which was fitted best among the different combinations tried for *Kuttanad* was , FBI = f (area, age, education, maxtemp1, rainfall1, maxtemp2, rainfall2, smaxtemp1, smaxtemp2, srain1, srain2)

The Fixed Effect mode was chosen for discussion based on the Hausman test and Prob> F value was found to be less than 0.05 indicating the goodness of the equation, as all the coefficients in the model are different from zero (Table. 4.2.4.1.)

Apart from the socioeconomic variables (area and age),temperature during the first phase of crop growth (November- December) was found to have a significant positive impact on farm revenue. An increase in 1^0C is likely to affect an increase of Rs.0.82 unit in FBI (Farm Business Income). But during second half, an increase in temperature leads to a decline in farm business income by 10.02 units.

Rainfall during the first phase of crop growth was found to have a significant positive impact on FBI. This may be due to the direct effect on crop growth due to better soil quality. The rain during this phase help to wash off the iron, manganese and aluminium from the acid sulphate soils of Kuttanad and facilitate crop growth. However during later stages, the rainfall hinders the production due to direct crop damage, or increased pest and disease outbreak. It may also hinder the timely management practices, sometimes. Over the years, the trend in maximum temperature and rainfall in this region is showing an increase of 0.12 per cent and 0.86 per cent respectively. If there is an increase in temperature by 1^0C and a rise in rainfall by 1cm during the initial stage of the crop, there would be a net positive impact on FBI by 0.82 units. If this increase in temperature and rainfall is received in the second half of the cropping season only, there would be net decline in income by 10 units. If these changes are there, both in the first and second half of the cropping season, there would be net decline of farm business income by 9 units.

Thus it can be concluded that, higher rainfall and temperature during the first phase(Nov-Dec) along with a static or reduced rainfall and temperature during the second half of the crop growth leads to better farm income. But, higher rainfall and temperature during both the phases result in a net decline in farm income. Same will be the effect if the temperature and rainfall increase during the second phase only.

Though the higher order factors of maximum temperature at the second half of the cropping season as well as rainfall in the first half of the cropping season are found to be significant, the impact these factors caused are indirect and will be significant in long run.

The impact of climate change in the paddy cultivation at *Kuttanad* is found to be a direct impact. Among these, an increased maximum temperature and rainfall during the first half of the cropping season coupled with a static or reduced level during the second half is desirable, since this is an ideal condition for realising better Farm Business Income.

Table 4.2.4.1. Parameter Estimates of Regression Equation- *Kuttanad*

Parametres	Coefficient	Standard Error	t value
Area	2.74*	0.29	93.32
Age	-0.06*	0.003	-20.7
Education	-0.15	0.21	-0.72
Maxtemp1	0.82*	0.3	2.69
Rainfall1	0.009*	0.001	4.91
Maxtemp2	-10.02*	1.99	-5.03
Rainfall2	-.009*	0.003	-3.05
S Maxtemp1	-0.01	0.004	-2.27
S Maxtemp2	0.14	0.02	4.89
S Rain1	0	6.93E-06	-6.94
S Rain2	0	0	1.99
Constant	159.13	32.88	4.84

(* Significant at 1 per cent level)

Among the various combinations of variables tried for *Kole* lands, the best fit equation was FBI = f(age ,smaxtemp1, smaxtemp2, srain1, srain2), The result of the analysis is furnished in table 4.2.4.2.

Table 4.2.4.2. Parameter Estimates of Regression Equation - *Kole*

Parametres	Coefficient	Standard Error	t value
Age	-883.45	6441.1	-0.14
S Maxtemp1	-2457.2	1994.4	-1.23
S Maxtemp2	4485.92*	1805.71	2.48
S Rain1	-4.19	6.26	-0.67
S Rain2	-8.76	41.14	-0.21
Constant	-252.64	20.11	-1.26

(* Significant at 1 per cent level)

In this model, none of the socioeconomic variables were captured. Among the weather variables, the square of the maximum temperature during the second phase of the crop season is the only variable which was found to have significant impact on Farm Business Income, though not direct. This is contrary to the results in *Kuttanad*, where increase in temperature and rainfall during the initial crop phase was desirable and those in second phase yielded negative impact. It is to be highlighted that, the weather data for *Kole* region is gathered from the Meteorological Station at College of Horticulture, Vellanikkara, which is on average, 20 kilometres away from the *Kole* lands. In *Kuttanad*, the weather data was gathered from Rice research Station, Mancompu, which typically represents the ecosystem. Moreover, the result, underlines the importance of location specific studies on the impact of weather variables on Farm Business Income and hence the need for establishing weather stations in such locations.

4.3. Public Costs of Weather Extremes (Summer Rain, *Kuttanad*, 2008)

The unexpected extremes in weather factors cause loss of life, and property. The major types of weather abnormalities are droughts and floods, heat and cold waves, excessive or defective insolation, thunder storms, lightening and hailstorms, dust storms, cyclones and anticyclones, high waves, forest fire, ice and snow storms and sea level rise (Rao *et al.,* 2008).

According to Disaster Management Institute, India, the direct disaster losses amounts to an average US $ 1 billion per year. This amounts to two per cent of our GDP. Further, up to 10 per cent of rural poor suffer due to loss of work or assets due to weather related disasters in India each year. About 60 per cent of land mass in India is vulnerable to earthquakes, 40 million prone to floods, eight per cent prone to cyclones and 68 per cent is susceptible to droughts. In India there were 30 flood events which caused 1150 deaths and property losses amounting to US$ 5000 million, of which US$770 only was insured. The excess monsoon rain between 25 June and 4 July 2005 caused more than 200 lives in Gujarat, 40,000 lost their property and the insured losses amounted to US$ 50m (World Bank, 2008)

In Kerala, the main type of weather extremes are associated with changes in rain fall pattern (floods, droughts, landslides) or associated atmospheric phenomenon (lightning). The years in which actual rain fall was above the normal by twice the mean deviation or more, is defined as years of floods or excessive rain fall. Some of the flood years, thus, in Kerala are 1994, 1998, 2005 and 2007 (Rao *et al.,*, 2008). However, definition can vary. For instance in *Kuttanad*, where the paddy fields are below Mean Sea Level (MSL), excessive rain cause break of the outer bunds and the salt water intrusion may harm the crop. So the crop loss may not be due to submergence. Continuous rain fall may hinder the timely farm operations (fertiliser applications, weed management, harvest etc.), which may also lead to crop loss/ damage. Rice in *Kuttanad* ecosystem has been under great threat of flooding due to the breach of manmade bunds or dykes. Later on public capital investments coupled with private participation has reduced the frequency of such catastrophe.

The rainfall during the main crop season of *Kuttanad i.e.* from November- December to March-April from is of vital significance in rice output. The harvesting of the main crop in *Kuttanad* is in March. The average summer showers during this season for the past 28 years range from a low of 6.4 mm (1992) to a high of 402 mm (1983). Excepting the extreme years (1980, 1983, 1984, 1989, 1999, 2005 and 2008) the range was 6.4 mms to 104 mms. The long term mean of ten years is 132.57mm. Thus, the average rainfall in March in *Kuttanad* in 2008 was 29 per cent higher than the long term mean (Table.4.3.1and Fig.4.3.1).

The torrential rain during this period, resulted in heavy loss to the farmers as it coincided with the harvesting of the crop. All the management expenses were incurred by that time, which maximizes the extent of loss. The loss was due to complete loss of the crop, partial damage or loss due to quality decline.

The 2008 summer rainfall caused complete loss of crop to 11,037 farmers in 6988.62 ha, spread in 434 padashekarams in Alappuzha (Table 4.3.3). Ramankary block suffered widespread damage in 3280.98 ha, affecting 3329 farmers. The extent of loss was lowest in Kayamkulum block. As a disaster management strategy, Government of Kerala provided Rs.695.09 lakhs to these farmers, at the rate of Rs.10, 000 per ha. Correspondingly, each farmer received Rs.6298, in proportion to the average crop area of 0.63 ha. The holding size was highest in (0.99 ha.) in Ramankary, and lowest in Chengannur block. The actual extent of loss suffered by the farmers (private cost), on account of the crop damage was calculated as the difference between forgone returns and the amount of compensation. Thus, the forgone returns, which the farmers could have realized in the absence of the flood damage was estimated based on the average returns realized by the sample farmers in the area (Rs.34,500/-) during that season. Thus the total forgone returns (damage cost) amounted to Rs.2454.13 lakhs. The extent of private damage cost, thus was Rs.1759.04 lakhs. The public cost amounted to 28 per cent of the total damage cost, and the rest 72 per cent was suffered by owner farmers.

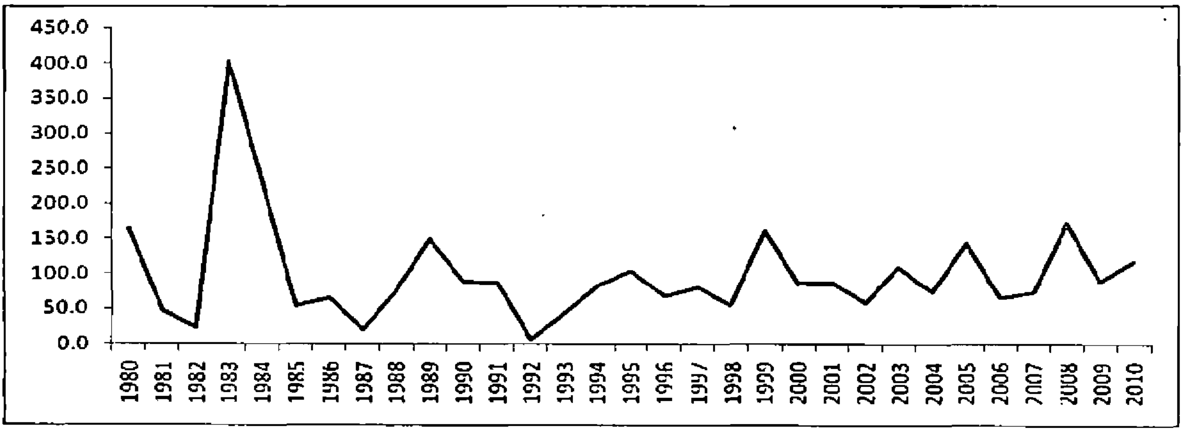
Table 4.3.1. Monthly (March) rainfall of Alappuzha district (1980-2010) (mms)

Year	Rainfall (mm)
1980	164.1
1981	48.0
1982	23.0
1983	402.0
1984	229.6
1985	54.9
1986	66.0
1987	19.7
1988	75.4
1989	149.3
1990	88.7
1991	87.6
1992	6.4
1993	42.6
1994	82.5
1995	104.3
1996	67.8
1997	81.0
1998	54.5
1999	162.0
2000	86.1
2001	87.2
2002	59.2
2003	109.8
2004	74.0
2005	144.1
2006	66.0
2007	74.2
2008	171.0
2009	88.7
2010	117.0

Table 4.3.2. Average Monthly Rainfall of Alappuzha District (2008) (mms)

Month	Rainfall (mm)
January	0
February	88.2
March	175.5
April	166.5
May	127.8
June	366.5
July	660.7
August	189.4
September	332.6
October	313.7
November	122.3
December	41.9

Fig. 4.3.1 Average Rainfall in March in Alappuzha district (1990-91 to 2008-09)(mm)



In some *Padasekharams*, farmers could harvest some portion of the area, and the loss was only partial. This area (4806.92 ha.) belonged to the 5245 farmers in 294 padasekharms in Alappuzha, Ambalappuzha, Ramankary and Champakulum blocks. A total compensation of Rs. 138.35 lakhs was paid to the affected farmers, on the basis of assessment by Department of Agriculture. On an average, the amount was Rs.2878 per ha, with a range of Rs.2147 (Champakkulam) to 5724

(Alappuzha). The total damage cost was worked out to Rs.1688 lakhs of which 92 per cent was private cost. The per head compensation amounted to an average Rs.2637.75 (Table 4.3.4).

Flooding of fully mature rice fields caused significant loss in quality of grains. Financial loss due to quality degradation of harvested grain was suffered by 300 farmers in 40 padasekharms. 11.41 lakhs tones of grains could not meet the market quality standards. The area equivalent of this was 475.36 ha. Rs.44.76 lakhs were paid as compensation to make good the losses at the rate of Rs.3.92 per Kg. The forgone benefits from this damage amounted Rs.166.93 lakhs, of which Rs.122.17 lakhs (73 per cent) was private cost (Table 4.3.5).

Thus, the summer showers of 2008 in Kuttanad area, resulted in a total damage cost of Rs.4309.06 lakhs, of which 79.62 per cent was private and the rest i.e.20.38 per cent was the public cost. This private and public cost amounted to Rs.3430.86 lakhs and Rs.878.20 lakhs respectively (Table 4.3.6). The total area equivalent affected was 32 per cent of total cropped area under paddy during the season amounting to 72 per cent of total paddy production in Alappuzha. This estimate includes only the loss due to crop (paddy) damage and do not account for the property loss and other damages.

On similar lines, Fernado *et al.* (2007), estimated the economic value of climate variability in terms of forgone/additional coconut production in Sri Lanka, employing percentile analysis of time series data. The forgone income to the economy was estimated to vary from US$ 32 million to 73 million, thus emphasizing the need for investments in adaptation. Barriopedro (2010) reports the damage due to mega heat waves in Russia, during summer, 2010. The extreme temperature across Russia resulted in a decreased wheat crop yield during 2010. The economic costs of this crop failure were reported as a loss of 30 million tons of $8.1 billion. This represents the direct loss to Russian agriculture. In addition, this crop loss as well as others elsewhere in the world for wheat and other staples, has constrained supply in the face of increasing demand worldwide, leading to sharp price increases.

Similarly, it is to be stated that the estimates of climate extreme event due to summer rain in Kuttanad in 2008, are modest, as it does not include other related costs due to property loss, damage to assets and infrastructure, additional expenditure for subsequent crops and the threat to food security. The extent of economic loss justifies the importance of public investment as to prevent damage costs due to weather extremes. The natural disaster management policy has been mostly post disaster management options. But the paradigm shift presently is preventive and pro poor. In *Kuttanad* there could be technological solution like development of rice varieties for short duration, tolerance to salinity, acidity, submergence/ water logging, pest and diseases, seed dormancy etc. to guard against such calamities, for which public investment can be made as a preventive, pre-disaster management option.

Table 4. 3. 3. Damage Cost of Weather Extremes due to Complete Crop Loss in Summer Rain, 2008

Blocks	No. of Padasekharams	No. of Affected Farmers	Area equivalent of crop damage (ha.)	Public Damage Cost (Rs Lakhs)	Total Damage cost(Rs lakhs)	Private Damage Cost (Rs lakhs)
Alappuzha	13	318	251.76	25.18	88.41	63.23
Ambalappuzha	65	938	516.57	51.66	181.40	129.74
Ramankary	143	3329	3280.98	327.17	1152.15	824.98
Champakkulam	105	2205	1396.48	139.65	490.39	350.74
Haripad	41	2451	996.17	99.62	349.81	250.19
Kayamkulum	8	59	21.30	2.13	7.48	5.35
Mavelikkara	10	640	222.08	22.16	77.99	55.83
Chengannur	49	1097	303.29	27.53	106.50	78.97
Total	**434**	**11037**	**6988.62**	**695.09**	**2454.13**	**1759.04**

Table 4.3.4. Damage Cost of Weather Extremes due to Partial Crop Loss in Summer Rain,2008

Blocks	No. of Padasekharams	No. of Farmers	Area Equivalent of Crop Damage (ha.)	Public Damage Cost (Rs Lakhs)	Public Damage (Rs/ha)	Total Damage Cost (Rs lakhs)	Private Damage Cost (Rs lakhs)
Alappuzha	9	453	242.80	13.90	5724.57	85.26	71.36
Ambalappuzha	36	423	340.00	10.31	3031.44	119.39	109.08
Ramankary	122	2461	2050.13	67.45	3290.06	719.92	652.47
Champakkulam	126	1907	2171.99	46.65	2147.80	762.72	716.07
Haripad	-	-	-	-	-	-	-
Kayamkulum	-	-	-	-	-	-	-
Mavelikkara	-	-	-	-	-	-	-
Chengannur	1	1	2.00	0.04	2169.00	0.70	0.66
Total	**294**	**5245**	**4806.92**	**138.35**	**2878.14**	**1688.00**	**1549.65**

Table 4.3.5. Damage Cost of Weather Extremes due to Poor Quality Grain Production in Summer Rain, 2008

Blocks	No. of Padasekharams	No. of Farmers	Damaged Grain(Kg)	Public Damage Cost (Rs Lakhs)	Area Equivalent (Grain/ Average Yield) (ha)	Total Damage Cost (Rs Lakhs)	Private Damage Cost (Rs lakhs)
Alappuzha	2	21	73837	2.30	30.77	10.80	8.50
Ambalappuzha	4	36	185602	7.42	77.33	27.16	19.74
Ramankary	17	169	580678	23.01	241.95	84.96	61.95
Champakkulam	16	71	279853	11.19	116.61	40.95	29.76
Haripad	1	3	20885	0.84	8.70	3.06	2.22
Kayamkulum	-	-	-	-	-	-	-
Mavelikkara	-	-	-	-	-	-	-
Chengannur	-	-	-	-	-	-	-
Total	**40**	**300**	**1140855**	**44.76**	**475.36**	**166.93**	**122.17**

Table4.3. 6. Total Damage Cost of Weather Extremes due to Crop Loss in Summer Rain, 2008

Blocks	No. of Padasekharams	No. of Farmers	Area Equivalent of Crop Damage (ha.)	Public Damage Cost (Rs Lakhs)	Total Damage Cost (Rs. Lakhs)	Private Damage Cost (Rs.Lakhs)
Alappuzha	24	792	30.77	41.38	184.47	143.09
Ambalappuzha	105	1397	77.33	69.39	327.95	258.56
Ramankary	282	5959	241.95	417.63	1957.03	1539.40
Champakkulam	231	4112	116.61	197.49	1294.06	1096.57
Haripad	41	2451	8.70	100.46	352.87	252.41
Kayamkulum	8	59	-	2.13	7.48	5.35
Mavelikkara	10	640	-	22.16	77.99	55.83
Chengannur	49	1098	-	27.57	107.20	79.63
Total	**739**	**15723**	**475.36**	**878.20**	**4309.06**	**3430.86**

4.4. Farmer's Perception and Adaptation Strategies to Climate Change

4.4.1. Farmer's Perception on Climate Change

The discussion on climate change has been limited in academic circles for long. But the recent mass media attention and the micro level weather aberrations have made the stakeholders aware of the phenomenon. Paddy farmers of the study area (*Kuttanad* and *Kole*) were also well aware of the climate change impacts. However, there is the general tendency to link all aspects of crop production to climate change effects. Table 4.4.1 presents the relative weights the farmers attach to the expressions of climate change impacts in agriculture.

Table.4.4.1 Farmers' Perception on Climate Change in the study areas

Sl. No	Impact	Farmers responded (%)	
		Kuttanad	*Kole*
1	Increase in temperature	100	100
2	Increase in pest and diseases	85	10
3	Aberrant rainfall	100	80
4	Flood (due to summer rain nowadays)	100	100
5	Rise in sea level	20	10
6	Decreased yield and there by threatened food security	100	100

Every farmer in *Kuttanad* and *Kole* (i.e. 100 per cent of the sample respondents of the study areas) opined that they are facing the ill effects of climate change in number of ways. All the sample respondents in both the study areas (*Kuttanad* and *Kole*) opined that, over the years, the temperature is increasing. 85 per cent of the respondent farmers at *Kuttanad* have perceived increased incidence of pest and disease outbreak associated with increased temperature. They have observed the emergence of minor pests as major pests and diseases becoming uncontrollable over the years.

Significant, unexpected shifts in rainfall pattern is reported as a major symptom associated with climate change by all the farmers in *Kuttanad* and 80 per cent in *Kole* lands. The traditional wisdom in predicting the rainfall, based on local symptoms often fail now and it makes farming difficult often. In olden days most of the critical farm operations were done based on such predictions and farming wisdom.

The unseasonal rain during the summer months, when the crop is ready to harvest, is another symptom of climate change, according to farmers. This makes the management very difficult, often leading to complete crop damage as in the case of summer rain in 2008 in *Kuttanad.*

Farmers of *Kuttanad* (20 per cent) and *Kole* (10 cent) have opined that they have heard of the phenomenon of rising sea level especially after the Tsunami event in 2004, though not directly experienced.

All the farmers responded very strongly on the negative impact of climate change on agricultural output. They have concluded that if climate change is not properly managed, food security will be in question. The widening gap in food production and requirement is a matter of concern for the state.

4.4.2. Adaptive Behaviour to Climate Change

Adaptation is defined as an evolutionary process through which population becomes better suited to conditions and habitats. This process takes place over many generations through experimentation and observation. Managing the impacts of climate change primarily include mitigation (actions that tackle the causes of climate change, such as reducing greenhouse gas emissions) and adaptation (actions that minimize the consequences of actual and expected changes in the climate). Adaptation is a way of reducing vulnerability, increasing resilience, moderating the risk of climate impacts on lives and livelihoods, and taking advantage of opportunities posed by actual or expected climate change. Improving social, economic and technical resilience and increasing flexibility within systems is a form of adaptation and allows further adaptation to take place more easily, for example by increasing water storage capacity and extending water supply services. Increasing adaptive capacity may be achieved through sustainable development, supporting the idea that adaptation activities can occur even in the face of uncertainty (Postnote, 2006).

Adapting to climate change entail adjustments and changes at every level – from community to national and international. Communities must build their resilience, including adopting appropriate technologies while making the most of traditional knowledge, and diversifying their livelihoods to cope with current and future climate stress. Local coping strategies and traditional knowledge need to be used in synergy with government and local interventions. The choice of adaptation interventions depends on national circumstances. To enable workable and effective adaptation measures, ministries and governments, as well as institutions and non-government organizations, must consider integrating climate change in their planning and budgeting in all levels of decision making (UNFCCC, 2007).

However, most of the developing countries, where the impacts of climate changes are predicted to be more intense, are constrained by physical, technological and financial resources to plan and implement adaptation strategies. Hence, there is global understanding on resource sharing for adaptation programme and funding for such activities by the developed countries to developing countries. For instance, to shed light on adaptation costs, a study on the Economics of Adaptation to Climate Change (EACC) was initiated by the World Bank in early 2008, funded by the governments of the Netherlands, Switzerland, and the United Kingdom. Its objectives were to develop an estimate of adaptation costs for developing countries and to help decision makers in developing countries understand and assess the risks posed by climate change and design better strategies to adapt to climate. The initial study report, which focuses on the first objective, found that *the cost between 2010 and 2050 of adapting to an approximately 2°C warmer world by 2050 is in the range of $75billion to $100 billion a year*. This sum is of the same order of magnitude as the foreign aid that developed countries presently give developing countries each year, but it is still a very low percentage of the wealth of countries as measured by their GDP. Stern (2006) estimated that that if we don't act, to avert the climate change effects, the overall costs and risks of climate change will be equivalent to losing at least five per cent of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20 per cent of GDP or more. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around one per cent of global GDP each year.

Since paddy production is predominantly conducted in developing countries, the situation for funding its adaptation to climate change is tightly linked to the "Adaptation Fund" that was launched at the 13th Conference of Parties (COP13) held in Bali in 2007. The principles of the Adaptation Fund have been reiterated in the Copenhagen Accord at COP15 (2009), namely, that *"Developed countries shall provide adequate, predictable, and sustainable financial resources, technology, and capacity building to support the implementation of adaptation action in developing countries."* In combination with funds allocated for mitigation, the collective commitment by developed countries accounted for US$30 billion for 2010-12. In line with the Bali road map, the Copenhagen Accord confirmed that "funding for adaptation will be prioritized for the most vulnerable developing countries that include the

LDCs". However, the Copenhagen Accord failed to deliver clear modalities and time lines for generating and distributing these envisaged funds.
The adaptation strategies which can be followed by developing countries include both modern technologies(to be developed) and traditional indigenous knowledge systems and socioeconomic and behavioral changes .UNFCC (2007) list out several mechanisms to combat the impacts like, development of tolerant/resistant crops (to drought, salt, insect/pests) research and development, soil-water management, diversification and intensification of food and plantation crops, policy measures, tax incentives/subsidies, free market and development of early warning systems. Devi and Rao (2008) reported the efficiency of early warning systems in managing climate related crop damages in Kerala. The study reported that the severity of damage due to climate change can be sizably reduced through efficient interventions for mitigation and adaptation strategies. Their analysis established a significant positive impact of Agromet Advisory Service on farm income. Hence they strongly recommend to adopt and strengthen the Agromet Advisory Services based on weather forewarning to include all aspects of farm management for sustenance of crop production and food security in the state of Kerala.

The scientific progress made in understanding the physiology of abiotic stresses and the development of biotechnology tools have opened up promising opportunities for making a significant impact through improved technology. However, as the 2008 rice crisis demonstrated, agricultural research in general remains grossly underinvested in developing countries in Asia. This is a cause for concern, not only for climate change adaptation and mitigation but also for promoting overall agricultural development (Wassman *et al.*, 2009).

Options for adaptation involve the adjustments which the farmers are making to decrease the vulnerability of rice production to climate changes. Crop rotation, changes in planting date, varietal selections with different duration are being practiced by farmers knowingly or unknowingly to combat climate change. This session discuss some of the strategies followed by the farmers in the study area, either deliberately or otherwise to adjust with the changing weather. Table 4.4.2.1explain the prominent adaptive behavior among farmers in the study area.

Table 4.4.2.1.Adaptive behavior of farmers in the study areas

SI.No	Strategies	Farmers Responded (%)	
		Kuttanad	***Kole***
1.	Planting Time Adjustments	31 (91)	32 (91)
2.	Varietal Selection	34 (100)	35 (100)
3.	Crop Rotation	2 (6)	1 (3)
4.	System of Rice Intensification	0 (0)	2 (6)
5.	Integrated Farming System	16 (47)	4 (11)
6.	Policy Interventions (Crop Insurance)	34 (100)	35 (100)

4.4.2.1. Planting time adjustments

High temperature during the flowering stage of rice crop cause spikelet sterility. Pang *et al.* (2004) suggested adjustments in planting time so that the reproductive and grain filling phases of rice fall in to those months with relatively low temperature. In tune with this, Kumary (2010) highlighted the importance of dissemination of information on delayed sowing / selection of appropriate planting date so as to escape from the high temperature during flowering of the crop, in Kerala to combat climate change impacts.

Majority of the farmers (91 per cent in *Kuttanad* and in *Kole*) followed this strategy. Since farming in *Kuttanad* and *Kole* ecosystems are collective in nature, adoption by one farmer in a *padasekharam* lead to adoption by the rest either due to better understanding or neighborhood effects. Traditionally the planting /sowing of rice crop used to be in the months of October in accordance with the onset of North East monsoon. Over the years the planting season is shifted to November, or even up to the end of December. This is a big problem for those farmers, who are taking the additional crop (May-June to September-October). If the additional crop is getting late for harvest, due to climatic or other reasons, naturally, the planting date of the *Puncha* crop also got late. All the farmers, whether they are taking or not taking the additional crop face problem due to the rainfall of North East monsoon. If the water from the *padasekharams* doesn't recedes by the time of planting, then also the farmers are forced to delay the sowing. For example, the nature of delayed sowing of Kainakari *padasekhaam* is represented in the table 4.4.2.2.

Table 4.4.2.2 Plating date of *Puncha* crop in Kainakari *Padasekharam*

Year	*Puncha*	
	From	To
1991	12/11/91	30/11/91
1992	10/11/92	28/11/92
1993	5/11/93	20/11/93
1994	10/11/94	30/11/94
1995	15/11/95	30/11/95
1996	22/10/96	30/11/96
1997	12/11/97	30/11/97
1998	2/11/98	21/11/98
1999	NA	NA
2000	7/11/00	14/12/00
2001	23/10/01	17/12/01
2002	17/10/02	19/11/02
2003	19/10/03	30/11/03
2004	25/10/04	16/12/04
2005	1/11/05	12/12/05
2006	27/10/06	30/11/06
2007	4/11/07	20/12/07
2008	7/11/08	30/12/08
2009	16/11/09	15/12/09
2010	13/11/10	21/12/10

There is a drastic change in the planting time of the *Puncha* crop. During 1990s, it was mostly the last week of November, which has slowly advanced to mid-late Decemberby late 2000s. This is mainly due to the changes in weather parameters.

4.4.2.2. Varietal Selection

Cultivation of rice varieties with greater tolerance to stresses such as heat, drought, flood, salinity and varieties which respond positively to high CO_2 can be adopted as an effective technological option (Challinor *et al.*, 2004). This necessitates investments in technology development or revival of traditional varieties which possess such characteristics. Kerala Agricultural University has released a number of varieties with different maturity periods, resistance to pest and diseases, tolerance to acidity, salinity and shallow flooding and seed dormancy, suited to the varying requirements of rice growing regions of Kerala. The table 4.4.2.3. shows different varieties released by Kerala Agricultural University.

Table 4.4.2.3 Varieties with Different Traits Released by Kerala Agricultural University

Sl. No.	Trait	Varieties
1	Short duration(100-110 days)	*Jyothi, Makom, Annapurna, Rohini, Kanchana, Harsha, Hraswa, Manupriya, Onam, Chingam etc.*
2	Resistance to Pest & Diseases	*Bhadra, Asha, Pavizham, Uma, Renjini, Gouri, aruna, Makom etc.*
3	Tolerance to acidity	*Karishma, Krishnanjana*
4	Tolerance to salinity	*Vyttila 1-7, Sagara*
5	Seed dormancy	*Uma, Revathy*
6	Submergence/ Waterlogging	*Neeraja, Sagara, Makaam, Kumbham*

Currently, the widely accepted variety of rice in *Kuttanad* area is *Uma* and that in *Kole* is *Jyothi*. All respondent farmers in the study area cultivate these varieties because of the high fertiliser responsive and photo insensitive nature as well as because of the higher yield traits. Earlier the common varieties in these ecosystems were *Kochuvithu, Kallada chempavu, Vaikkatharyan (Kuttanad)* and *Chempavu , Vykkatharyan and Kulappala* (*Kole*). But, all these shifts cannot be attributed to climate adaptation strategies alone.

However, more research is to be initiated to incorporate a range of "defensive traits" in to a single variety so that cultivation of such varieties result in higher adaptation to climate change impacts and also to the resultant extreme weather conditions (Kumary, 2011)

4.4.2.3. Crop rotation

Crop rotation is one of the strategies that adapt crops to biotic stresses. Wassman *et al.*, (2009) opined that crop rotation has the ability to reduce the impacts of biotic and abiotic stresses, whose intensity is likely to increase with climate change.

Only six per cent of the farmers in *Kuttanad* and three per cent respondent farmers from the *Kole* reported as following crop rotation in their field. Fish, prawn or sesame crop is usually rotated after the rice crop.

4.4.2.4. System of Rice Intensification (SRI)

System of Rice Intensification (SRI) offers a very viable strategy to counter climate change risk. In this system, the length of the crop cycle is reduced while the yields remain high. There is better resistance of SRI rice plants to lodging due to wind/ rain because of their large root systems and stronger stalk (Stoop *et al.*, 2009). SRI methods reduce the agronomic and economic risks that farmers face with the advent of climate change. But a study from *Kole* (Sindhu, 2008). reported that the yield from the SRI system was low compared to the normal recommended practice of cultivation. SRI system is generally suited to the water scarce regions. A modified SRI with 2-3 seedlings per hill, fertiliser and chemical application at the needed times can only make the system of SRI economically viable (Sindhu, 2008). Only six per cent of farmers at *Kole* follow the system, which can be categorized as a modified SRI. None of the farmers at *Kuttanad* follow this technology.

4.4.2.5. Integrated Farming Systems

Salinger and Stigter (2000) reported that multiple enterprise agriculture consisting of crop, livestock, poultry, fish farming and trees in a single unit of land will ensure protection against projected loss due to climate change and also will benefit from on farm resource use. Behera *et al.,(*2008) also confirmed this fact. Thus enterprise diversification is one of the most widely suggested technologie to minimize risk. 47 per cent of respondent farmers in *Kuttanad* and 11 per cent farmers in *Kole* have gone for diversification. The prominent components in this system are cattle, duck and poultry in *Kuttanad* and cattle and poultry in *Kole* lands. As agriculture is the main source of income for the farmers of *Kuttanad,* diversification of the enterprises are very much needed. But, for the farmers of *Kole,* agriculture is not the sole source of income; hence farmers are reluctant to go for diversification.

4.4.2.6. Policy interventions

Just as the developing economies are not able to find funds for mitigating and adapting to climate change, the small and marginal farmers do not have the financial and technological resources to manage the disaster. This warrants the support by the governments to provide policy support for minimizing the loss and protecting against damages.

Crop Insurance was suggested as a climate risk management tool as early as 1992 by UNFCCC, and included in the 1997 Kyoto Protocol and the 2007 Bali Action Plan. The Bali Action Plan calls for "consideration of risk sharing and transfer mechanisms, such as insurance" to address loss and damage in developing countries, particularly vulnerable to climate change.

Since late 1940s, India debated the feasibility of crop insurance schemes. It was in 1970s that, the first concrete attempt of crop insurance was made possible. The first crop insurance was started in 1972 for cotton in Gujarat, and it covered nearly 3000 farmers with a claim of Rs. 37.90 lakhs, and the project has got a humble end in 1978. A Pilot Crop Insurance scheme for cereals, millets, pulses, oilseeds, cotton and potato was implemented from 1979 to 1984. It covered 6,27,000 farmers with a paid indemnities of Rs.157 lakhs. An expansion of this Pilot Crop Insurance Scheme was then made compulsory for borrowing farmers from 1985-1999. The scheme was for cereals, millets, pulses, oilseeds. It was implemented in 16 states and two Union territories, covered 763 lakh farmers with a paid indemnities of about Rs. 231900 lakhs. Since 1999, National Agriculture Insurance Scheme is covering about 20 million farmers annually with 35 different crops in Kharif and 30 different crops in Rabi.

Insurance schemes specially designed to cover weather related risks were introduced by Agriculture Insurance Company of India. The pilot weather risk index based insurance project in 2004 was created to protect for the loss due to deviation in crop output due to weather condition. And a location specific Weather Based Crop Insurance Scheme (Pilot Project) was started in 2007-08 by the government. Cereals, Pulses, Oilseeds, Commercial crops and perennial horticultural crops are being covered by this scheme, in India.

Weather Based Crop Insurance Scheme (WBCIS) is a unique Weather based insurance product designed to provide insurance protection against losses in crop yield resulting from adverse weather incidences. It provides payout against adverse rainfall incidence (both deficit & excess) during Kharif and adverse incidence in weather parameters like frost, heat, relative humidity, un-seasonal rainfall etc. during Rabi. It is not yield guarantee insurance. Weather insurance has been piloted in the country since Kharif 2003 season. Some of the States where it's piloted are Andhra Pradesh, Chattisgarh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab and Rajasthan.

Weather Based Crop Insurance aims to mitigate the hardship of the insured farmers against the likelihood of financial loss on account of anticipated crop loss resulting from incidence of adverse conditions of weather parameters like rainfall, temperature, frost, humidity etc. While Crop insurance specifically indemnifies the cultivator against shortfall in crop yield, Weather based Crop Insurance is based on the fact that weather conditions affect crop production even when a cultivator has taken all the care to ensure good harvest. Historical correlation studies of crop yield with weather parameters help us in developing weather thresholds (triggers) beyond which crop starts getting affected adversely. Payout structures are developed to compensate cultivators to the extent of losses deemed to have been suffered by them using the weather triggers. In other words, Weather based Crop Insurance uses weather parameters as 'proxy' for crop yields in compensating the cultivators for deemed crop losses. Weather based Crop Insurance Scheme (WBCIS) operates on the concept of "Area Approach" i.e., for the purposes of compensation, a 'Reference Unit Area (RUA)' shall be deemed to be a homogeneous unit of Insurance. This RUA shall be notified before the commencement of the season by the State Government and all the insured cultivators of a particular insured crop in that area will be deemed to be on par in the assessment of claims. Each RUA is linked to a Reference Weather Station (RWS), on the basis of which current weather data and the claims would be processed. Adverse weather incidences, if any during the current season would entitle the insured a payout, subject to the weather triggers defined in the 'Payout Structure' and the terms & conditions of the Scheme. The "Area Approach" is as opposed to "Individual Approach", where claim assessment is made for every individual insured farmer who has suffered a loss.

In addition to the Weather Based Crop Insurance, weather based agromet advisory services also can be strengthened in Kerala following the success story in paddy. Study conducted by Devi and Rao (2008), reported the significant positive impact of agromet advisory services on farm income from paddy. Impacts of climate change can reduce sizably following the agromet advisory services. Hence agromet advisory service based on weather forewarning may be strengthened to include all aspects of farm management for sustenance of paddy production and food security in Kerala.

All the farmers of the study area responded positively towards the adoption and improvement of the policy interventions to save the crop from damage and loss due to the unpredictable nature of weather parameters.

SUMMARY

Chapter V

Summary

Impact of climate change on agriculture is projected to be severe, especially in developing economies. Due to the socioeconomic, geographic and climatic diversity in India, the impacts vary across regions. The economic impact of climate change, through its effect on paddy output in Kerala was undertaken in this background. The study on "Climate change impacts and adaptation strategies in paddy production" was undertaken during the agricultural year 2010-11. The main objectives of the study were to quantify and value the impact of climate change on paddy production, to assess the public cost of mitigation strategies of weather extremes and to understand farmer's level of understanding and adaptive mechanisms to climate change.

The major paddy growing tracts of Kerala, viz. Alappuzha (*Kuttanad*) and Thrissur (*Kole*) districts were selected as the study area. Multi stage random sampling was the method of sample selection. Time series data (1980-81 to 2007-08) on the cost of cultivation and returns from paddy cultivation was gathered from 35 each respondent farmers from *Kuttanad* and *Kole* from farm records maintained by them. The secondary data for the study was collected from Department of Economics and Statistics, Department of Agriculture, Indian Meteorological Department, Cooperative societies of farmers of the respective areas and Research stations of Kerala Agricultural University. The analysis was done employing Ricardian Approach for the panel data of 70 farmers (35 each from both study area) for quantifying the economic impact of climate change in the paddy production scenario.

Kerala state has been a food deficit state since its inception. Currently, the paddy production in the state is enough to meet only one sixth of domestic requirement. At the same time, area under the crop shows steady decline at the rate of 3.06 per cent per annum (1980-2008).This is attributed to a host of social and economic forces which lead to conversion of paddy lands to other purposes. The conversion was faster in Thrissur district (3.47 per cent) compared to Alappuzha (1.93 per cent). Correspondingly, paddy production in the State was showing a decline at the rate of 2.16 per cent. In Thrissur district, the fall was to the tune of 1.72 per cent as against 0.70 per cent in Alappuzha. However, it is relieving to note that the productivity is showing a positive trend, though modest.

The financial performance of paddy farming is one of the deciding forces for farmers to remain in farming. The total paid out cost of paddy cultivation in the state (2007-08) was

estimated at Rs. 20,980/ ha. which was up by 24 per cent in Alappuzha and 36 per cent in Thrissur, due to the peculiarity in cultivation. Human labour was the largest single item of expenditure (53.5 per cent), followed by manures and fertilizers (14 per cent). The scarcity of skilled labour, thus poses serious problem in this sector.

The average yield realized by the farmers in Kerala was 2.4 tonnes/ ha as against the potential yield of 3.32 t/ha (for *Uma* at Rice Research Station, Mancompu) and the national figure of 3.21 t/ha. Though Department of Economics and Statistics estimates showed yields of 2.4t/ha, the farmers in Kole area reported higher yield realization. Thus the Gross Returns amounted to an average of Rs.35,462 for the state, with a BC ratio of 1.69. The corresponding figures for Alappuzha are Rs 34,565 and that for Thrissur Rs. 35,567. As per primary data, the Gross Returns in *Kuttanad* was Rs.34,500 with BC ratio of 1.32 and in *Kole,* it was Rs.44,700 with BC ratio of 1.56. Generally, the average yield of paddy in Alappuzha (*Kuttanad*) and Thrissur (*Kole*) are reported as almost on par at 3 t/ha. The low yield of paddy in Alappuzha (*Kuttanad*) in 2007-08 may be due to the heavy summer rainfall, which caused severe crop loss to the farmers.

The Farm Business Income (Gross returns-Cost A_1) from the crop was Rs.14,482 in Kerala and Rs.8,412 in Alappuzha and Rs.16,155 in Thrissur. With an average holding size of 1.93 ha. in *Kuttanad,* the Farm Business Income was only Rs.16,235 and that in *Kole* lands (average holding size 1.84 ha) was Rs.29,725. At state level, this amounted to Rs.14,482. This income was enough to meet the household consumption requirement for only 1.5 months in Kuttanad and 2.8 months in Kole areas. Further, the time series data on Gross Returns reflected an increasing trend in current prices, but a stagnant or decreasing trend at constant prices. Thus it could be seen that the economic indicators do not very much favour paddy farming.

Agriculture production in general is dependent on weather factors, along with other socioeconomic forces. Kerala state is reported to be slowly moving from wetness to dryness. The maximum temperature in the state showed an annual rate of increase of 0.02 per cent over a short span of 28 years and it was a high 0.12 per cent in Alappuzha (*Kuttanad*). In *Kole* region, however, there was a marginal decline (-0.07 per cent). The variability in maximum temperature was not very high, and was almost on par in *Kole* and *Kuttanad* region, and showed lower variability than that of the state level data. The minimum temperature exhibited a lowering tendency for the state as a whole (-0.03 per cent), though it was not so in the two study regions (0.05 per cent and 0.09 per cent respectively in *Kuttanad* and *Kole*). Excepting *Kuttanad* (0.86 per cent), rainfall was decreasing in the state (-0.09 per cent) and Thrissur (-0.67 per cent). The heavy summer showers in *Kuttanad* must have been the reason for a positive figure for this region. The variability in rainfall was a high 14.11 per cent in Kerala, 13.54 per cent in *Kole* and 6.93 per cent in *Kuttanad.* These results highlight the regional variation on weather behavior and underlines the need for location specific approach.

For assessing the economic impact of climate change on paddy production, Farm Business Income (Gross Returns- Cost A_1) was regressed with the socio economic parameters (area of land under cultivation of *puncha* (summer) crop, age and education of the respondent farmers) and climatic variables (mean maximum temperature and mean rainfall in the first and second halves of the cropping season). The impact of climate change on the paddy production in *Kuttanad* is found to be direct. Apart from the socioeconomic variables (area and age), temperature during the first phase of crop growth (November- December) was found to have a significant positive impact on farm revenue. An increase in 1^0C is likely to affect an increase of Rs.0.82 unit in FBI (Farm Business Income). But during second half, an increase in temperature leads to a decline in farm business income by 10.02 units. Rainfall during the first phase of crop growth was found to have a significant positive impact on FBI. Thus it can be concluded that, higher rainfall and temperature during the first phase (Nov-Dec) along with a static or reduced rainfall and temperature during the second half of the crop growth leads to better farm income. But, higher rainfall and temperature during both the phases result in a net decline in farm income. Same will be the effect if the temperature and rainfall increase during the second phase only. In *Kole* lands, among the weather variables, the square of the maximum temperature during the second phase of the crop season is the only variable which was found to have significant impact on Farm Business Income (+35.6 per cent increase), though not direct. These results, underline the importance of location specific studies on the impact of weather variables on Farm Business Income and hence the need for establishing weather stations in such locations.

One of the major objectives of the study was to estimate the public cost of expenditure towards mitigating the climate extreme event in *Kuttanad* (the summer rain, 2008). The summer showers of 2008 in *Kuttanad* area, resulted in a total damage cost of Rs.4309.06 lakhs, of which 79.62 per cent was private and the rest i.e.20.38 per cent was the public cost. This private and public cost amounted to Rs.3430.86 lakhs and Rs.878.20 lakhs respectively .The total area equivalent affected was 32 per cent of total cropped area under paddy during the season amounting to 72 per cent of total paddy production in Alappuzha. This estimate includes only the loss due to crop (paddy) damage and do not account for the property loss and other damages.

All the respondent farmers were aware of the concept of climate change. Respondents in both the regions attribute increased temperature, unseasonal rainfall and flood as the most important symptoms associated with climate change. 85 per cent farmers in *Kuttanad* believe that higher incidence of pest and diseases as a consequence of rising temperature. Farmers perceive a negative impact on paddy production, which is a threat to food security for the state.

Some of the behavioural changes in paddy farming sector include change in planting time of the crop, choice of improved varieties, crop rotation, integrated farming and System of Rice Intensification. Farmers also opt for policy intervention to promote paddy production and reduce the vulnerability to risks. These adaptive strategies are not perhaps in response to climate change alone, but in response to a host of social, economic and climatic forces. However, these are indicative of the possible adaptation mechanisms, which are socially acceptable.

Policy Suggestions:

1) The rate of decline in area and production of paddy in *Kole* area was found to be more rapid. Hence there should be region specific programmes to sustain paddy farming in the area.
2) The income from paddy farming in the major crop season in *Kuttanad* and *Kole* areas is enough to support the household expenditure only for 1.5 to 2.8 months in an year. Moreover, over the years, the real FBI shows a steady or declining trend. This situation calls for income support measures for the farmers, if they have to remain in this vocation.
3) The changes in weather parameters vary significantly across the regions, within the state, and the weather extremes are also region specific. So investment on weather based agro advisory services can, to a large extent, help the farmers to manage and adapt to climate change impacts.This naturally necessitates establishment of weather stations in these critical production ecosystems.

4) Farmer education on the potential impacts and adaptation strategies on climate change can be done through extension progrmmes.

5) Research & Development- strengthening of the research and development system is advocated to develop new strategies on the adaptation and mitigation of climate change impacts.

6) Currently, the public management programme towards damages due to weather extremes are mainly event specific and post damage compensation packages. There is a need for a permanent Crisis Management Fund for *Kuttanad* and *Kole.*

7) The Weather based Crop Insurance programme is not seen enjoyed by majority of farmers. The scheme may be made popular, especially in these two major rice growing tracts.

8) The model developed for the regions are indicative in nature. This may be validated with larger database and more location specific weather variables.

Future line of work:

This study has concentrated on paddy production in two major growing centres. It may be extended to other major rice growing tracts. Further the economic impact of climate change on the major cash crops (Coconut, Spices, and Plantation crops) of Kerala is to be conducted.

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APPENDICES

Appendix I

Department of Agricultural Economics

College of Horticulture

Kerala Agricultural University

Vellanikkara

"Climate Change Impacts and Adaptation Strategies in Paddy Production"

Questionnaire

1. Name of the Krishibhavan 2. Name of *Padasekharam*
3. Name of the respondent
4. Address

5. Household Information

Sl.No	Relation with head (code)	Sex	Age in years	Education	Primary occupation
1					
2					
3					
4					
5					

Sex: 1. Male 2. Female

Education : 1. No schooling, 2. Primary school, 3. Upper Primary, 4. High school (upto tenth), 5. Higher secondary, 6. Graduate, 7. Post graduate, 8. Others (specify)

Occupation : 1. Agriculture only, 2. Govt. employee, 3. Private employee, 4.Own business, 5. Agricultural labourer, 6. Non agricultural labourer, 7.not working, 8. House wife, 9. Student

Relation with Head : 1. Head, 2.Wife, 3.Son, 4. Daughter, 5. Son in law, 6. Daughter in law, 7. Sister, 8. Brother, 9. Grandson, 10. Granddaughter, 11. Others (specify)

6. Land particulars

Sl.no.	Particulars	Wetland	Garden land	Dry land	Total
1	Area owned				
2	Area leased in				
3	Area leased out				
4	Net sown area				
5	Area sown more than once				
6	Net irrigated area				

7. Details of the land under study

Sl.no.	Crop season	year	Area (cents)	Variety

8. Implements and machinery owned by the farmer

Sl.no	Particulars	Number	Year of purchase	Subsidy	Original vaue	Present value	Whether used in paddy cultivation

9. Livestock owned by the farmer

Type	Number	Breed	Year of purchase	Whether used in paddy cultivation

10. Bullock/ Machine labour used

Sl.no	Farm operation	Bullock/ Machine labour	Duration	Prevailing rate (Rs/acre)	Payment in kind (if any)	Value of Kind payment

11. Labour use pattern

Sl No	Particulars	Family labour (hrs)		Hired labour (hrs)		Prevailing wage rate/hrs of work			Contract payment (Rs/acre)	Wage in kind	Value of kind payment
		Men	Women	Men	Women	Hrs of work	Men	Women			
1	Dewatering										
2	Ploughing										
3	Repair of inner bunds										
4	Levleling										
5	Seed preparation										
6	Sowing										
7	Gap filling										
8	Application of soil ameliorants										
9	Manure application										
10	Fertilizer application										
11	a)I application										
	b)II application										
	c)III application										
12	Weed control										
13	Pest control operations										
14	Harvesting										
15	Post harvest operations										

Total cost of cultivation=

Yield =

Returns=

Input used	Time of application (DAS)	Source of purchase	Quantity applied		Rate	Subsidies if any		Transportation cost	Other expenses
			Unit	Quantity		Rate per Unit	Total Amount		
Seed									
Manures									
Fertilizers									
I.Application									
Urea									
SSP									
MOP									
Complex									
II.Application									
Urea SSP MOP Complex									
III.Application Urea SSP MOP Complex									
Soil ameliorants 1. Lime 2. Calcium Carbonate									
Weedicides 1. 2. 3.									
Insecticides/Fungicides 1. 2. 3. 4.									

Other information:
Awareness and Adaptation strategies:-

1. Have heard of the term "climate change" – yes/ no

2. Do you think that the climate change is there in your ecosystem? – Yes/ no

3. What have you perceived as the impacts of climate change?

Sl.no	Impacts
1.	
2	
3	
4	
5	
6.	
7.	
8.	
9.	
10.	

4. What are the strategies for climate change in your opinion?

Sl.no	Strategies
1.	
2	
3	
4	
5	
6.	
7.	
8.	
9.	
10.	

Appendix II

a) *Kuttanad* -Weather data

Year	Max temp 1	Max temp 2	Rainfall 1	Rainfall 2
1980	31.6	32.05	254.55	31.5
1981	31.15	32.3	165	1.9
1982	32.75	32.4	222.65	0
1983	32.05	32.95	144	77.4
1984	32.1	32.25	60.4	87.5
1985	32.25	33.15	109.9	22.3
1986	33	33.6	162.5	20.9
1987	33.05	33.95	146.1	17.35
1988	32.9	33.45	41.2	10
1989	32.4	32.85	104.95	23.7
1990	32.95	32.155	158	0.3
1991	32.65	31.96	106.25	22.5
1992	32.1	32.54	80.61	1
1993	32.2	32.345	119.45	13.5
1994	32.2	32.4	56.9	0.4
1995	36.75	33.25	84.8	10.3
1996	33.1	33.4	125.7	2.4
1997	33.7	35.2	209.1	19.7
1998	28.6	31.8	122.1	9.05
1999	32.75	34	63.95	105.5
2000	31.3	32.75	87.45	73.15
2001	28.68	32.4	43.2	0
2002	32.55	32.85	157.6	29.5
2003	32	33.4	47.7	15
2004	32.6	32.75	82.2	15.35
2005	31.2	33.17	142.3	6
2006	32.4	31.75	137.05	15.25
2007	31.75	32.15	89.9	44.1
2008	37	33.75	82.1	45.3

b) *Kole*- Weather Data

Year	Max temp 1	Max temp 2	Rainfall 1	Rainfall 2
1980	32.95	34.8	90.05	0
1981	31.2	33.5	40.1	0
1982	31.65	33.8	51.8	0
1983	31.5	33.35	42.3	13.95
1984	32.25	33.65	12.1	7.35
1985	32	33.35	36.6	1.55
1986	31.85	34.1	93.5	0
1987	31.6	34.1	144.5	3.9
1988	32.6	34.85	12.95	0
1989	32.6	34.2	4.05	1.75
1990	31.75	34.75	35.8	1.95
1991	31.7	33.55	95.75	0
1992	31.05	33.35	189.75	3.3
1993	31.55	33.85	46.3	10.55
1994	32	34.15	62.65	0.25
1995	32.1	33.9	44.2	0
1996	31	32.95	41.95	0
1997	31.65	33.75	139	0
1998	30.8	33.45	71.2	11.4
1999	31.05	33.1	4.55	2.3
2000	31.85	33.55	26.25	6.1
2001	30.55	33.55	57.9	0
2002	32.05	33.95	11.05	81.05
2003	31.85	34.3	9.1	0
2004	31.1	34.15	35.85	3.8
2005	31.1	33.4	7.4	0
2006	31.6	33.25	39.75	0
2007	31.65	32.95	16.75	14.85
2008	31.9	33.95	12.15	0
2009	31.65	33.7	111.65	0

Appendix III

a) Descriptive Statistics (*Kuttanad*)

Variable	Observations	Mean	Standard Deviation	Minimum value	Maximum value
returns	1020	4.088226	3.22482	0	32.81
area	1020	1.575833	1.186494	0	10
age	1020	42.82353	11.85363	5	69
mintemp1	1020	23.35117	1.191724	21.045	26.5
maxtemp1	1020	32.40933	1.614336	28.6	37
rainfall1	1020	120.1937	54.06796	41.2	254.55
mintemp2	1020	22.62733	1.355784	20.35	26
maxtemp2	1020	32.87067	.7573575	31.75	35.2
rainfall2	1020	22.90833	27.23457	0	105.5
_est_fixed	1020	1	0	1	1
_est_random	1020	1	0	1	1

b) Descriptive Statistics (*Kole*)

Variable	Observations	Mean	Standard Deviation	Minimum value	Maximum value
returns	988	77350.49	1518219	658	4.77e+07
area	988	2.445091	4.129907	.3	32
mintemp1	988	22.80972	.4841529	21.8	23.8
maxtemp1	988	31.6793	.5142782	30.55	33
rain1	988	52.46179	46.28414	4.05	189.8
mintemp2	988	22.47333	.6017787	21.35	23.8
maxtemp2	988	33.81048	.4853467	32.95	34.9
rain2	988	5.729403	15.09654	0	81.1
age	988	40.58907	12.35055	5	69
education	988	9.540486	2.425669	4	15
smaxtemp1	988	1003.842	32.58795	933.3024	1089
smaxtemp2	988	1143.384	32.90819	1085.703	1218.01
srain1	988	4892.293	8057.067	16.4025	36024.04
srain2	988	260.5008	1212.492	0	6577.21
_est_fixed	988	1	0	1	1
_est_random	988	1	0	1	1

CLIMATE CHANGE IMPACTS AND ADAPTATION STRATEGIES IN PADDY PRODUCTION

By

SUSHA P.S.

ABSTRACT OF THE THESIS

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ABSTRACT

The impact of climate change is predicted to be more pronounced in developing countries like India as these economies mainly rely on climate sensitive sectors and the resources to manage are scarce. There exists wide variability in the socio economic conditions and geography across India and hence the impact of changes in climate varies across regions and locations. The study entitled "Climate change impacts and adaptation strategies in paddy production" in Kerala was undertaken with the objective of valuing the impact of climate change on paddy production and assessing the public cost of weather extremes .The study also explored farmer's level of understanding on the concept of climate change and farm level adaptive mechanisms.

The study was based on both primary and secondary data. The two major rice growing tracts of Kerala, viz. Alappuzha (*Kuttanad*) and Thrissur (*Kole*) districts were selected as the study area. Multistage random sampling method was adopted for sample selection. A random sample of 35 each farmers were identified and time series data (1980-81 to 2007-08) on the cost of cultivation and returns from paddy cultivation was collected from the records maintained by them. Further, the primary data on adaptation strategies and awareness level were gathered through personal interview method using pretested interview schedule. Ricardian approach using the panel data was employed to analyse the impact of change in climate on the paddy production. Apart from this, averages, percentages, growth rates and coefficient of variation were also used in the analysis.

The area under paddy farming in Kerala has been exhibiting a declining trend for the past few years. During 1980-81 to 2007-08 the decline was to the tune of 3.06 per cent. The domestic production of paddy has never been able to meet the requirement and the gap is widening due to further falling trends (-2.16 per cent per annum). Though the area and production trends were negative, the productivity trends showed a slightly positive sign with 0.94 per cent. There is wide variability in the performance of these indicators across the regions.

The poor performance of paddy cultivation in the state has, largely been attributed to social (labour shortage, scarcity) and economic (relative profitability) reasons. The Gross returns from paddy farming amounted to an average of Rs 35,462 for the state, with a BC ratio of 1.69. Farm business Income in Kuttand was only Rs.16,235 and that in *Kole* lands (average holding size 1.84 ha) was Rs.29,725. At state level, this amounted to Rs.14,482. This income was enough to meet the household consumption requirement for only 1.5 months in *Kuttanad*

and 2.8 months in *Kole* areas. Further, the time series data on Gross Returns reflected an increasing trend in current prices, but a stagnant or decreasing trend at constant prices. Thus it could be seen that the economic indicators do not very much favour paddy farming.

The weather variables in Kerala has been changing in such a way that it caused the state to shift from wetness to dryness. Minimum temperature and rainfall recorded a negative growth rate over the years, with a compound annual growth rate of -0.03per cent and -0.09 per cent respectively and maximum temperature shows a positive growth rate of 0.02 per cent. There was very high variability in minimum temperature and rainfall in Kerala compared to maximum temperature. The pattern of changes shows distinct differences in magnitude and direction in each location.

The Ricardian Method of analysis have shown that maximum temperature and rainfall during the initial growth phase(first two months) of the crop in *Kuttanad* region as exerting significant positive impact on farm income while these variables during second phase cause a decline in income. In *Kole* lands, however, it was the reverse and temperature during the second phase of crop growth was found to have positive and significant impact, though not direct

The extreme events associated with climate change cause damage to property and life. The direct damage costs associated with the summer rain in 2008 amounted to Rs 4309.06 lakhs, of which 79.62 per cent was private and the rest i.e.20.38 per cent was the public cost. The total area equivalent affected was 32 per cent of total cropped area under paddy in *Kuttanad* during the season, amounting to 72 per cent of total paddy production in Alappuzha.

Farmers in these regions were following several alternate management options like, planting time adjustments, varietal selection, crop rotation, System of Rice intensification (SRI), integrated farming systems and protecting against potential risk through subscribing to crop insurance.

The farmers in general are aware of the climate change phenomenon, and majority state rising temperature as the most significant symptom of climate change. Increased outbreak of pests and diseases, changes in rainfall patterns, floods and sea level rise are also considered as symptoms of climate change by these farmers.

The study highlights the need for detailed research on the topic covering different ecosystems and suggests location specific weather based agroadvisory services. The study justifies the public sector investment towards mitigating and adaptation programmes. The need for educating and empowering the stakeholders and developing a disaster management system to manage climate extremes is also underlined. The weather based crop insurance scheme, presently not very popular may be further promoted. The study also highlights the need for income support programmes for paddy farmers, as an incentive to continue in farming ,in the context of rising food security concerns.