Adaptation Practices to Climate Change by Paddy Farmers: A Study of Wayanad and Palakkad Districts in Kerala

A Thesis Submitted to the University of Hyderabad in partial Fulfilment of the Requirement for the Award of

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in

Economics

By

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CERTIFICATE

This is to certify that the dissertation entitled **"Adaptation Practices to Climate Change by Paddy Farmers: A Study of Wayanad and Palakkad Districts in Kerala"** submitted by **BASHEER.K. K.** bearing registration number 12SEPH20 in partial fulfilment of requirements for the award of the degree of Doctor of Philosophy in the School of Economics is a bonafide work carried out by him under my supervision and guidance. The thesis is free from plagiarism and has not been submitted previously in part or whole to this or any other University or institution to award any degree or diploma. The candidate has satisfied the UGC Regulations of publications and conferences presentations before submitting his thesis. Details are given below.

A. Publication:

1. Published a paper with Dr. G. Sridevi (Associate Professor, University of Hyderabad) "Effects of Adaptation to Climate Change on Technical Efficiency of Paddy Farmers in Panamaram", Natural Volatiles & Essential Oils, 2021; 8(4):6258-6275. https://www.nveo.org/index.php/journal/article/view/1299

B. Presentations in Conferences:

1. Presented a paper: "Review on the Impact of Climate Change on Indian Economy", at the National Webinar on Indian Economy- A Kaleidoscope of 75 Years, organized by P.G Department of Economics, NMSM Government College Kalpetta, Wayanad Kerala, on 03.11.2021.
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Further, the student has passed the following courses towards fulfilling the coursework requirement for PhD and was exempted from doing coursework (recommended by the Doctoral Committee) based on the following course passed during his M.Phil program, and M.Phil Degree was awarded.

Course Code	Course Title	Credits	Pass/Fail
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SE-702	Social Accounting and Data Base	4	Pass
SE-703	Research Methodology	4	Pass
SE-751	Study Area	4	Pass
SE-752	Dissertation	16	Pass

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This is to state that the thesis entitled "**Adaptation Practices to Climate Change by Paddy Farmers: A Study of Wayanad and Palakkad Districts in Kerala**" submitted to the School of Economics, the University of Hyderabad for the award of the degree of Doctor of Philosophy in Economics, is the original work done by me under the supervision of DR.G.SRIDEVI, Professor, School of Economics, University Of Hyderabad; and the same has not previously formed the basis for the award of any degree, diploma, Associateship, fellowship or any other similar title of recognition. I hereby agree that my thesis can be deposited in Shodganga/INFLIBNET.

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To all the people in my life who touch my heart, I dedicate this research

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LIST OF ABBREVIATION

IPCC	Intergovernmental Panel on Climate Change
BC	Brundtland Commission
UNFCCC	United Nations Framework Convention on Climate Change
CR	Club of Rome
LGM	Limits to Growth Model
UNCHD	United Nations Conference on Human Development
WCS	World Conservation Strategy
IUCN	International Union for Conservation of Nature
WCED	Word Commission on Environment and Development.
GDP	Gross Domestic Product
KSACC	Kerala State Action Plan on Climate Change
CDB	Community Development Block
DEA	Data Envelopment Analysis
TE	Technical Efficiency
SFA	Stochastic Frontier Analysis
OECD	Organization for Economic Co-operation and Development
DFSRF	Driving Force State Response Framework
TFP	Total Factor Productivity
AS	Agriculture Sustainability
SD	Sustainable Development
IGP	Indo-Gangetic Plains
RWCS	Rice Wheat Cropping System
SRI	System of Rice Intensification
BCSD	Brundtland Commission on Sustainable Development
SMI	Sequential Malmquist Index
HYV	High Yielding Varieties

MFC	Marginal Factor Cost
MVP	Marginal Value Product
THI	Temperature Humidity Index
ETI	Equivalent Temperature Index.
RKVY	Rashtreeya Krishi Vikas Yojana.
SDPA	Sustainable Development Program in Agriculture
RIF	Rise Innovation Fund
JLG	Joint Liability Group.
SAZ	Special Agricultural Zone
MSP	Minimum Support Price
FCI	Food Corporation of India
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
GRT	Garret Ranking Technique
AP	Adaptation Strategies
CAS	Common Adaptation Strategies
AP	Coping Strategies
CAP	Common Coping Strategies
CAS	Complementary Adaptation Strategies
CAS	Complementary Coping Strategies
MLE	Maximum Likelihood Estimate

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The concept of "sustainable development" has its route from the 12th century BC onwards in connection with forest management (Ehnert, 2009). However, the term has gained momentum since the Neo- Malthusian[1] Club of Rome (CR) works on the development called the 'Limit to Growth' (LG) published by a group of scientists led by Dennis and Meadows in 1972 (Grober, 2007). It was the first work that tried to analyse sustainable development more or less in a contemporary sense. Moreover, it uses the term sustainability to indicate sustainable modal of output production without immediate catastrophic collapse and meeting the basic material requirements of all people. Later, the concept was taken to denote under the label eco-development (Adams, 2007). Sustainable development became even more central after two publications, first by 'World Conservation Strategy (WCS) in 1980 by the "International Union for Conservation of Nature" (IUCN) (Leal, 2015). Second by foundation report (Brundtland Report, 1987) entitled "Our Common Future" by the "World Commission on Environment and Development" (WCED) in 1987 (ibid, 2015).

Later, during the 1990s, a growing body of scientific research released by the "Intergovernmental Panel on Climate Change" (IPCC) in its major reports has confirmed that current climate change is real and anthropogenic (IPCC, 2014). In connection with the ongoing climate change, there have been observable changes in the global average earth and ocean temperature, uncertain variability in regional rainfall patterns, shifting of ecological zones, sea level rises, melting of polar ice caps , besides extreme weather conditions such as "drought and flooding in various parts of the world" (Philander, 2008). Climate change will have an impact on every economic sector. However, as it is a climate-dependent and sensitive sector, "agriculture is arguably one of the sectors which are most

[1] The Club of Rome is a multi-national, informal, non-political club of scientists, scientists, educators, and business leaders concerned about global environmental issues. (Club of Rome proposal 1970). The main focus of the Club of Rome is on global demographic and economic growth issues. In order to solve perceived problems of environmental deterioration, it promotes a neo-Malthusian goal of limiting population increase and fostering sustainable economic development. The Club of Rome's first report, The Limits to Growth, is the most well-known. (Encyclopedia.com).

damaged by climate change" (Fróna et al., 2021); therefore, it will be more vulnerable to climate change (Barros et al., 2014).

The agriculture sector can be sustainable and adverse impacts of future climate changes can be ameliorated when it can cope and adapt to climate change (UNFCCC 2008, FAO 2016). In general, the Brundtland Commission (BC) gives a precise definition of sustainable development[2] resulted in the rapid growth of literature on sustainability (Cordonier et al, 2004). The concept of sustainable agriculture also gained momentum with the Brundtland Report in 1987 (Velten, et al., 2015). However, agriculture has been one of the areas of research where scholars do not have a consensus on what constitutes sustainable agriculture.

There are various definitions of agriculture sustainability in the literature given by different scholars. Agriculture sustainability has been classified into several categories, including sustainability as "an ideology, a set of strategies, the ability to achieve a wide set of goals, and the potential to continue into the future" (Hanson, 1996). Pretty (2008) interprets "sustainability as the development of the technologies and practices that do not have an adverse effect on the farming environment, accessible and effective for farmers, [and] maintain agricultural productivity over a long period". Monteith (1990) defines that a farming "system is sustainable over a defined period if outputs do not decrease when inputs are not increased". Conway (1985) argues that "sustainability is the ability of a system to retain productivity in the face of a substantial disturbance, such as is caused by intensive stress or a huge perturbation". While directly applying Brundtland's definition, Gray (1991) states that agriculture sustainability is the "maintenance of the net benefits agriculture provides to society for present and future generations".

While most of the studies have taken Conway's (1985) and Pretty's (2008) conception of agricultural sustainability as a useful starting point for their empirical studies, studies tend

[2]Sustainable development has been defined in many ways. However, a widely quoted definition can be found in Brundtland's report called 'Our Common Future' (OCF). The definition is "sustainable development that meets needs of the present without compromising the ability of future generations to meet their own needs."

to use either the analyses of productivities or the efficiencies. In the climate change context, it can be argued that the maintenance of long-term productivities despite disturbances/perturbations along with the adoption of adjustment practices with both the short term and long-term end in view in the form of respective coping strategies and adaptation practices to climate change may be necessary for agriculture system to be sustainable. However, the treatment of these two aspects---long-term positive trends in productivity and impacts of climate change adaption strategies and coping mechanisms---together in the context of climate-induced risks has been rarely addressed in the empirical studies of agriculture sustainability. Therefore, the present study attempts to understand climate change adaptation practices and coping mechanisms in influencing agricultural technical efficiency.

The remaining parts of this chapter have been organised in the following ways. Section 1.2 discusses major issues from literature, with research gaps. Section 1.3 deals with the significance of the present study. Section 1.4 describe the objectives of the present study. Section 1.5 and its subsections describe the detailed methodology and description of the study's data sources. Section 1.6 deals with the whole organisation of the thesis. The last section is about the limitations of the present study.

1.2 Major Issues from Review of Literature

Many studies seek to evaluate the performance of agriculture using one of two methods. The first method examines the agriculture sector's "Total Factor Productivity" (TFP) growth, decomposing the sources of input growth in total output growth. (Sidhu et al. 1991, 2005, Dholakia et al. 1993, Kumar. S et al. 2004, 2008, 2006, Desai et al. 1997, Evenson et al. 1998, Fan et al. 1999, Janaiah et al. 2005, Joshi et al. 2006, Chand et al. 2012, Birthal et al., 2014). These studies decomposed the share of technical change and input growth from output growth. The hypothesis is that a more significant contribution of technology changes components in output growth indicates that a lower share of input reliance and technological changes leads to lower production costs. In this sense, long-term maintenance of a positive trend in TFP shows improved performance because such development benefits both consumers and producers. However, in the context of climate and technology change, TFP growth is a misleading metric since it ignores improvements in technical efficiency, which perhaps stems from climate change-induced adaptation and coping mechanisms that significantly affect farm efficiencies.

The second method separates output growth into technological change, technical efficiency changes, and input growth. Such literature assumed that greater responsiveness of technical efficiency to output components indicates a shift toward sustainability. Research by Kalirajan et al., (1981, 2006), Huang et al., (1984), Ray (1985), Fan et al., (1991), Chaudhary (2012), Shanmugam et al. (2006), Makki et al. (2012), Auci et al. (2014), and Pradhan et al. (2018) attempted to incorporate technical efficiency components in their productivity studies. Many of these studies have used stochastic frontier analysis to analyse technical efficiencies of farming and their farm-specific determinants. However, they could not look into particular "adaptation practices" and "coping strategies" specific to climate change, although it influences production efficiency. Nevertheless, few new works of literature seek to analyse the effects of climate change adaptation strategies on agricultural technical efficiency regarding foreign countries, (Otitoju et al. (2014), Roco et al. (2017), Shimada et al. (2019) Owoeye (2020), Adzawla et al. (2021).

With regard to Indian agriculture, studies that use stochastic frontier analysis to link the effects of climatic conditions on technical efficiency are rare. Vijayasarathy et al. (2015) used stochastic frontier analysis in one study to explain the effects of technology adoption on the climate in the context of Tamil Nadu agriculture. Kumar.S et al., (2019) used "Data Envelopment Analysis (DEA), a non-parametric approach" in another study to assess the effects of input-use efficiency of climate-resilient technology adaptors in paddy and wheat crops with reference to Punjab agriculture in India. However, both works of literature ignore the effects of specific adaption factors and coping strategies on technical efficiency. Furthermore, studies in this genre fail to distinguish between "adaptation practises" and "coping strategies".

The present study hypothesised that agriculture is considered sustainable when increased adaptation and coping strategies improve production efficiency. Therefore, farmers' input variables in the production process will improve technical efficiency by adopting adaptation practices and coping strategies. It is so assumed that no productivity studies have been conducted to include such concerns of climatic risks and uncertainties in agriculture sustainability.

Paddy cultivation will be sustainable in the face of “climate change and variability” if it adapts to and copes with changes both in the short and long term. While "adaptation to climate change" is an adjustment practice carried out in the long-term to create opportunities and reap benefits, whereas coping strategies are those adopted to ameliorate the adverse “impact of climate change” for quick relief in the short term. Therefore, adaptation and coping practices to climate change increase productivity and “technical efficiency”. Hence, the present study examines "the effects of adaptation practices and coping strategies" to climate change on the "efficiency of paddy cultivation".

1.3 Significance of Study

Agriculture has long been an essential part of the Economies of the developing countries. Contributions of this sector to national economies GDP is declining, while the growing population's reliance on employment and livelihood is increasing (FAO, 2004). In the Indian economy, agriculture supports more than 70% of the population and employs more than 60% of the workforce, contributing almost less than 17% of GDP (Reddy. et al., 2010). Recently, visible policy, technological, and environmental fatigues have limited agriculture's ability to realise its full potential. (Behera et al. 2007).

In its major assessment reports, the "Intergovernmental Panel on Climate Change" (IPCC) unequivocally states that "ongoing climate change is real and occurring" (Solomon et al., 2007). As mentioned above, there is a sudden change in global average temperature, melting of polar ice caps and sea-level rise, the resultant drowning of coastal zones, changes in the rainfall pattern, shifting of ecological zones , in addition to the extreme climatic conditions experienced in different parts of the world (ibid). Even though every sectors of the economy impacted by the ongoing climate change (Kahn, 2019), since it is fundamentally a natural adjunct and climate-dependent, adverse effects will be felt more on the agriculture sector and hence become more vulnerable.

Against the background of ongoing changes in the climate, adaptation and mitigation are the two policy responses (Locatelli 2011). Mitigation is anthropogenic intervention at the individual, national, and global levels to reduce greenhouse gas sources or increase sinks . It is the concept of "controlling or limiting greenhouse gas emissions so that total accumulation is limited" (IPCC, 2014). Whereas adaptation policies involve an adjustment in the natural or human system in response to actual or expected climatic stimuli or their effects which moderates harms or exploit beneficial opportunities (ibid). It is the motion of making changes in the way we do things to respond to changes in climate (ibid). Given the differentiated responsibility for the cause of ongoing climate change by nations and public-good nature and its uncertainty of unequal benefits by nations, the adaptation option has distinct advantages over mitigation. Furthermore, its advantages are felt both in the long run and at the local level.

The agriculture sector needs to be sustainable in the context of “climate change” (FAO, 2017). The agriculture sector's vulnerability to climate change can be significantly reduced and made more sustainable when the system can cope with and adapt to climate change (UNFCCC, 2007). Total factor productivity is an index number-based approach (Sidhu et al. 1991, 2005, Dholakia et al. 1993, Kumar et al. 2004, 2008, 2006, Desai et al. 1997, Evenson et al. 1998, Fan et al. 1999, Janaiah et al. 2005, Joshi et al. 2006, Chand et al. 2012, Birthal et al., 2014) and stochastic frontier analysis is a production function approach (Kalirajan et al.,1981, 2006, Huang et al.,1984, Ray 1985, Fan et al., 1991, Chaudhary 2012, Shanmugam et al. 2006, Makki et al. 2012, Auci et al. 2014, and Pradhan et al. 2018) are the two main approaches used in the literature to examine sustainable agriculture.

Using stochastic frontier analysis, some researchers have attempted to link climate variability with agricultural technical efficiency. (Amin et al., 2012, Deep 2012, Makki 2012, Shimada 2014); however, overlook impacts of adaptation on agriculture performance. There is a small body of emerging literature (Otitoju et al., 2014, Vijaya et al. 2015, Lisandro et al., 2017, Muhammed et al., 2018, Shimada et al., 2019, Owoeye 2020, Adzawla et al ., 2021) that examines the role of adaptation practises on technical efficiency with reference to foreign countries using a stochastic frontier production function, but, did not differentiate adaptation practices and coping strategies to climate change and their differential role in influencing the performance of agriculture.

Although there are two studies (Vijayasarathy et al. 2015, Kumar et al. 2019) focusing on Indian agriculture that attempted to examine the implications of climate change adaptation on technical efficiency , no studies have used stochastic frontier analysis to examine the “effects of adaptation practices and coping strategies” on technical efficiency in the context of Kerala agriculture. Therefore, the present study investigates the differential role of adaptation techniques and coping strategies on the “technical efficiency” of paddy farming in Kerala using a “stochastic frontier production function” approach.

1.4 Objectives of the Study

The broader objective of the present study is to understand the farmers' adaptation practices and their effects on technical efficiency in the context of climate change. The specific objectives are;

1. To study the performance of paddy cultivation in Kerala.
2. To look into the changing context of paddy cultivation in Wayanad and Palakkad
3. To understand the paddy farmers “adaptation practices and coping strategies to climate change” in Kerala.
4. To examine “the effects of adaptation practices and coping strategies” on the “technical efficiency” of paddy cultivation in the Wayanad and Palakkad districts of Kerala.

1.5 Methodology of the Study

The broader objective of the present study is to understand the performance of the paddy farming system. The two main approaches used in the literatures to understand the performance of the agricultural system are assessing long-run productivity and technical efficiency of the farming system. The former approach concentrates on the improved productivity over the long run that must come from the betterment of knowledge, innovations, research, development activities and learning by doing , which enable farms to produce more output from given input resources. At the same time, the latter approach emphasises bringing actual output closer to the potential output by using existing input resources better. The present study uses a latter approach to look into aspects of the performance of the agriculture sector.

1.5.1 Theoretical Structure

Many studies with foreign countries have investigated the relationship between climate variability and technical efficiency. Mugera et al. (2012) investigated the impact of climate variability on-farm production efficiency in Kansas, United States . The impact of climatic variability on "total farm income, crop income, and livestock income" is treated using a "fixed-effects panel regression model", while the impacts of temperature and precipitation are modelled using multiple "stochastic production frontier" specifications. According to the study, climate variability has a considerable impact on mean output elasticities with respect to "input, return to scale, and technical efficiency". Capital and labour are more vulnerable to climate change than purchased inputs.

Mukherjee et al. (2012) investigate "the potential impact of heat stress on milk production efficiency in a sample of dairy farms in the southeast United States". The study's econometric models aid in quantifying the gross benefits anticipated as a result of climatic adaptation, as shown by the "Temperature Humidity Index (THI) or the Equivalent Temperature Index (ETI)". “Stochastic production frontier analysis” assesses the “technical efficiency” of an unbalanced panel of 103 dairy farms in Florida and Georgia. Five different model specifications are considered. According to the data, THI and ETI had a strong nonlinear negative influence on milk production. The climatic indices absorb some of the output shortages that would otherwise be attributed to inefficiency when they are included in the frontier specification. The findings also demonstrate that utilising fans in combination with sprinklers is a good way to compensate for output losses caused by heat stress.

Makki et al. (2012) and Auci et al. (2014) used stochastic frontier analysis to investigate "the effects of climatic factors on technical efficiency". However, they could not identify specific adaptation practices related to climate change that influence efficiency. In addition to climatic factors, socioeconomic factors in the context of climate change at various levels may impact agricultural production technical efficiency, which has been disregarded in their studies.

Using the "propensity score matching" approach, Shimada et al. (2019) reveal that climate change adaptation in the form of climate-smart agriculture enhanced rice farmers' technical efficiency by 13-14 per cent higher than non-adapters. Vijayasarathy et al. (2015) investigated the factors of climate adaptation technology and their impact on the technical efficiency of major crop production using a "multi-nominal logit model" and a "stochastic frontier production function". According to the study, using technology to adjust to climatic variability improves agricultural production “technical efficiency” significantly, whereas farmers' “adaptation to climate change” is limited by a lack of financial resources, technological understanding, and a high cost of adaptation.

Few recent works of literature used stochastic frontier analysis to evaluate the implications of “climate change adaptation” options on agricultural “technical efficiency”. Among the most important strategies for adapting to climate change are the following: "multiple cropping, land fragmentation, multiple planting dates, mulching and cover cropping" (Otitoju et al. 2014), "improved irrigation facilities" (Roco et al.2017), "soil conservation" (Mohamud Salat et al. 2018), "crop diversification, land fragmentation, use of improved verities and multiple planting dates" (Owoeye 2020), "row planting, changing planting dates, mixed farming, refilling, and intercropping" (Adzawla et al. 2021). While farmers implement adaptation strategies with a long-term goal in mind, others are coping strategies with a clear focus on short-term benefits. Neither coping nor adaptation strategies have been explicitly defined in any investigations. The existing research aims to understand better the impact of coping and adaptation strategies on technical efficiency in the face of climate change.

1.5.2 Technical Efficiency.

The technical efficiency of farming may be understood by comparing realised and potential output values from their respective minimisation and maximisation problems. The formal definition for technical efficiency can be found in Koopmans

(1951) work, holding the view that technically efficient one would produce the same output using at least less of one input. In other words, it uses the same input to produce at least more of one output. Later Farrell (1957) introduced the measurement of technical efficiency in economics, defining it as an ability or willingness to produce large possible output from inputs given the level of technology and resources.

Technical efficiency and allocative efficiency are two types of economic efficiency for decision-making units. The former refers to an economic unit's ability and willingness to achieve the maximum potential output from a given set of inputs and technologies . At the same time, later implies the ability and willingness of an economic unit to equate its specific marginal value product with its marginal cost (Kalirajan et al., 1999). The advantage of measuring technical efficiency is that it facilitates the comparison of the relative efficiency of different identical farms . Another advantage of measuring technical efficiency is that variations in technical efficiencies of different farms lead to investigating causes for such variation in technical efficiencies . Furthermore, analyses provide important policy implications for enhancing the technical efficiency of farms (ibid).

The decomposition exercise of TFP growth from empirical studies reveals that technical efficiency is essential for output growth. Therefore, it is hypnotised in the present study that "climate change adaptation" practices adopted by the farmers are likely to make them technically more efficient. If farmers can better adjust to the existing technology, it indicates two things. First, the farming system will be more efficient when farmers make amendments in their input to suit climate change. Second, adopting better adaptation practices to climate change will help farmers remain more efficient and productive in farming and ensure the "sustainability of the farming activity in the context of changes".

An alternative way to understand the farming system's sustainability is to examine the efficiency of the farm decision units Koeijer et al. (2002) and Vasavada (2018). The stochastic frontier production function is mainly used in the literature to study the technical efficiency of farms. However, in the context of measuring the sustainability of the farming system, studies are few. One study by Koeijer et al. (2002) measured agriculture sustainability in efficiency using Data Envelop Analyses (DEA) and found a positive correlation between technical efficiency and sustainable efficiency. Another study by Reinhard et al. (1999) used the “stochastic frontier approach to measure technical and environmental efficiency”. Another study by Hepelwa (2013) employed a “stochastic frontier approach to measure technical efficiency” indicators constructed from socioeconomic and watershed-related variables to obtain sustainability indicators.

Using the stochastic frontier approach, production efficiency is defined as the difference between the output at the frontier level and the actual output below the frontier level. That is, by addressing the constraints for maximising actual output up to the frontier level of outputs, which involves dealing with technical inputs under the farms' limit. Therefore, this method distinguishes between those controlled and uncontrolled inputs for influencing the technical efficiency of farms. In reality, farmers adjust to the technical conditions by managing controlled factors. However, in case of uncontrolled weather changes and other shocks, technical efficiency improvement can be accomplished by implementing adaptation measures. Therefore, "in the context of climate change", farmers might be taking into account or perceiving climatic variability in their farming decision, which would lead farmers to follow adaptation practices to improve farming efficiency. Therefore, it can be argued that improvement in the technical efficiency of farming is accomplished by adjusting not only to technical inputs but also to specific factors to address environmental changes caused by climatic variability in our case. However, this aspect has received little attention in agricultural technical efficiency studies, particularly in the “context of climate change”.

There exist few studies with respect to foreign countries that deal adaptation of farming could lead to improved technical efficiency of the farms. This study also hypotheses that farmers' adaptation practices to the controlled factors in the production function to perceived climate change may have a more significant influence in determining the efficiency of the farming system. This method can identify inefficiencies that can be corrected by adopting the best practices to adapt to climate change with uncontrolled factors. As a result, it is hypothesised that farmers who adopt better climate change adaptation practices will be more technically efficient farming systems. This analysis aims at helping policymakers to design compatible technological responses to climate change, where they can encourage farmers to implement those practices in the farm fields.

1.5.3 Analytical Framework

The concept of efficiency is commonly used to analyse the performance of a production unit.[3] Paddy farming is technically efficient as a production unit if it can produce the highest possible output from a given set of inputs. "In this study, the concept of technical efficiency is used to analyse the performance of paddy cultivation in the context of climate changes. The use of this in the present study has the following advantages. The study assumes that paddy farmers who use various coping strategies and adaptation practices will be more efficient. Therefore, there are policy implications for improving efficiencies in such analyses by considering better climate change adaptation options. In other words, appropriate adaptation practices that contribute to increased paddy cultivation efficiency can be identified" *.

There are two approaches; non-parametric and parametric approaches to measuring a production unit's efficiency. Firstly, the non-parametric model estimation technique called the "Data Envelop Analysis (DEA)" uses only input and output data. It is deterministic because any deviation from the maximum possible output is attributed to inefficiencies. Second, "Stochastic Frontier Analysis" (SFA) is a "parametric

[3] Efficiency can be of two types. 1-Allocative efficiency: Allocative efficiency is defined as the ability and willingness to use the quantity of inputs that will maximise net revenue (profit), given the current conditions of factor supply and market demand (Kalirajan et al., 1999). 2- Technical efficiency defined as the ability and willingness of farms to produce the maximum possible output with a specified quantity of inputs, given the prevailing technology and environmental conditions. In other words, a farm is said to be technically efficient, if it is able to realise the full potential of its technology with a given set of inputs(ibid). Technical efficiency is further subdivided into input and output oriented technical efficacy. The latter refers to a production unit's ability to produce the maximum possible output from a given set of inputs, whereas the former refers to a production unit's ability to produce a given level of output from the lowest possible input costs.

* Effect of adaptation to climate change on technical efficiency of paddy farmers in Panamaram" NVEO, (2021) Basheer K K, G Sridevi. The some of the result of the case study for Wayanad district is published in the said journal as part of the present PhD research.

approach" for estimating the coefficients of independent input variables in the production function. Furthermore, Stochastic Frontier Analysis considers random error, which arises from typical stochastic and natural inefficiencies. The present study uses stochastic frontier production specifications to fit the study's objectives best.

1.5.4 Stochastic Frontier Analysis

Stochastic Frontier Analysis is used in the present study to assess the performances of farm production systems at the micro-level. The stochastic production frontier models used in this study were simultaneously introduced by Aigner, Lovell, Schmidt (1977) and Meeusen Van den Broeck (1977).

The production function can be specified in the equation (Batese & Coelli 1992)… (1).

$$\boldsymbol{Y_i = \beta_0 + \beta X_i + \varepsilon_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Here,

$\boldsymbol{Y_i}$ is the log of paddy output, $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_i}$ are parameters.

$\boldsymbol{X_i}$ is the $\boldsymbol{Zx1}$ vector of input quantities, and $\boldsymbol{\beta}$ is the $\boldsymbol{Zx1}$ vector of parameters to be estimated. $\boldsymbol{\varepsilon_i}$ is a composite error term, $\boldsymbol{-u_i}$ is the technical inefficiency error, and $\boldsymbol{v_i}$ is the usual statistical random error or noise. $\boldsymbol{\varepsilon_i = -u_i + v_i}$ is assumed to be independently and identically distributed $\boldsymbol{N\ (0,\sigma_v^2)}$ and independent of $\boldsymbol{u_i}$, while $\boldsymbol{u_i}$ are non-negative random variables, assumed to be independently and identically distributed as truncated normal; $\boldsymbol{u_i \sim iidN^+(0,\sigma_0^2)}$

The equation (1) can be alternatively written as

$$\boldsymbol{Y_i = f(X_i\,;\beta)exp\ (u_i - v_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \textbf{(2)}$$

Herer $\boldsymbol{f}(.)$ can assume different functional forms such as Cobb-Douglas and translog functional forms. In the present study, the production function assumes the Cobb-Douglas type since the elasticity of substitution is estimated at a constant level. From equation (2), the technical efficiency of the paddy farmers can be defined as

$$TE_i = \frac{Y_i}{Y_i*} = \frac{f(X_i\,;\beta)exp\,(v_i\,\text{-}u_i)}{f(X_i\,;\beta)exp\,v_i} \text{ ………………… (3)}$$

The numerator in equation (3) is the actual observed output, and the denominator is the potential frontier output determined by the best production practices . Therefore

$$TE_i = exp\,(u_i) \text{ ………………… (4)}$$

Following the estimation of technical efficiency scores for individual paddy farmers, the next steps are to understand the effects of the farmers' socioeconomic characteristics, coping strategies, and adaptation practices on technical efficiency . The technical inefficiency model can be specified in (5)

$$U_i = \delta_0 + \sum_{n=1}^{k} \delta_i Z_j \quad \text{………………………… (5)}$$

Where U_i denotes the inefficiency effects. δ_i denotes coefficients of climate change adaptation practices, coping strategies and socioeconomic factors while Z_j is the vector of factors influencing technical inefficiencies . The Maximum Likelihood method developed by Battese and Coelli (1995) is used to obtain estimates for the stochastic frontier and the inefficiency model in a single step.

1.5.5 Empirical Model

The estimation of output, input variables, and coefficients can be specified empirically

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6\text{"……..(6).}$$

Y = Total quantity of Paddy output(kg), explanatory variables X_1 **to** X_6 measure inputs such as the area under paddy cultivation (acres), human labour in man-days, seeds(kg), organic manure(kg) and chemical fertiliser (kg), pesticides (litres), and β_1 *to* β_6 measures their respective parameters.

An empirical model for the effects of farm-specific socioeconomic features, adaptation practices, and coping strategies on technical efficiency/inefficiency can be given as in (7).

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6\text{………(7)}$$

Where $\boldsymbol{\delta_1}$ to $\boldsymbol{\delta_4}$ indicate farm-specific socioeconomic factors that affect efficiencies, such as the farmer's years of education, farm household size, farmer age, and year of farm experience. Education is projected to negatively associate with technical inefficiencies since more years of education provide farmers with up-to-date information to cope and adapt to changing climates, resulting in lower inefficiencies. The projected association between farm family size and farm inefficiency is positive because more household members engaged in farming increases routinised and hard menial labour, which lowers farm efficiency. Because farmer technical inefficiency reduces as the farmer gets to experience it, the relationship between farmer experiences and technical inefficiency is likewise expected to be negative. As farmer ages, they become less capable of carrying out every day agricultural tasks; consequently, technical inefficiency is projected to have a positive association.

Farmers “adaptation and coping strategies to climate” variability are included in the model as factors influencing paddy cultivation's technical efficiency. A farmer may employ single or several practices to adapt to climate change. As a result,“they are complementary rather than substitutable”. Therefore, in the present study, parameters $\boldsymbol{\delta_5}$ to $\boldsymbol{\delta_6}$ demonstrate complementary coping strategies and complementary adaptation practices, respectively. Paddy farmers employ a variety of coping measures, including delayed sowing, summer ploughing, a changeover between direct sowing and transplanting, additional irrigation facilities, drought-tolerant/resistant seed varieties, drip irrigation, continuous cropping, and crop insurance. Because adaptation and coping strategies are complementary, more and more farmer-joined practices help farmers cope and adapt to climate variability. As a result, it is expected that the relationship between mean adaptation and coping strategy scores and technical inefficiency will be negative.

Mixed farming, changing cropping patterns to grow less water-intensive crops, building farm ponds, increasing non-farm employment, increasing the number of livestock, particularly milch animals and goats, installing new borewells, shifting from crops to tree crops, migration, lift irrigation, and changing cropping patterns are all adaptation measures used by paddy farmers in response to climate change . The expected relationship between complementary adaptation strategies and technical inefficiency is negative as more and more adaptation practices in combination employed by the paddy farmers are likely to reduce their technical inefficiencies

The variance of random errors, σ_v^2, and that of technical inefficiency effects σ_u^2 and the overall variances $\sigma^2 = \sigma_u^2 + \sigma_v^2$ of the model are related. The ratio $\gamma = \sigma_u^2 / \sigma_v^2$ is called Gama, which measures the total variation of output from the frontier that can be attributed to technical inefficiency.

1.5.6 Data Sources

The first specific objective of the present study is to examine the performance of paddy production in Kerala based on technical efficiency. Secondary data sources for the state-level paddy output were collected for the present study. The data on paddy output has been collected from the various reports of Agriculture Statistics, published by the Directorate of Economics and Statistics, Govt of Kerala. Data on total input costs, including categories A, B, and C, were incorporated in the study. Inputs data were collected from the annual report on the cost of cultivation of crops of Kerala, Dept. of Economics and Statistics, Govt of Kerala. Primary data is used for studying the effects of adaptation practices on technical efficiency. Primary data is collected from the selected study area of Palakkad and Wayanad of Kerala state.

Kerala agriculture has undergone three different phases since independence. It can be classified as from 1950-1960, 1960-1990, and 1990 to present or labelled as the “pre-green revolution period, the green revolution period, and the post-reform period”. The present study is carried out for post-1990s when the issue of climate change has got a more significant currency among academicians, policymakers, researchers, scholars, and students. The impact of climate change trends on the production environment is typically felt for a long period. Moreover, temporal dimensions of the sustainability of the production process can be studied based on time series data. Although Kerala's agricultural stagnation began in the early 1970s, stagnation in paddy cultivation was particularly felt in the later 1980s (Kannan, 1988). However, this study uses secondary data between 2000 and 2018 to study the cost efficiency of paddy cultivation in

Kerala. Data related to climate change variable is collected from the NASA power access. The primary data collection of Wayanad districts has been carried out in September to November 2019. However, after a period of one year break due to the outbreak of covid 19 pandemic, primary data collection from Palakkad district was delayed and conducted during the time of earlier relaxation of covid protocols from April to June 2021.

1.5.7 Study Area

The study's first objective is to understand the performance of paddy cultivation in Kerala. Long-term policy, technological, and environmental challenges have hampered paddy production in Kerala (Thomas, 2011). The area under cultivation, paddy production, and productivity have all declined (Abraham 2019). At present, Kerala had a rice shortage of 83.45 per cent in 2009-10 (Karunakaran, 2014). The agricultural production slowdown began in the mid-1970s. (Kannan, 1988, 1990). The natural disaster that hit the state in the form of flood and landslide in 2018 and 2019 had affected the agricultural sector the most (Economic Review 2020). The agriculture sector in Kerala has been facing challenges with regard to its growth (ibid). Against this backdrop, the present studies were conducted to determine the performance of Kerala agriculture's paddy cultivation.

The second and third objectives of the study are to understand the effects of paddy farmers' adaptation practices and coping strategies on climate change using primary data collected in Kerala's Wayanad and Palakkad districts. Wayanad and Palakkad are among Kerala's four major climate change hotspot districts (KSACC 2014); therefore, they were selected as the study area. A district-level analysis of climate change hotspots reveals that farmer resilience to climate change is low due to various social, economic and geographical factors. Wayanad and Palakkad districts are vulnerable to extreme climatic conditions such as drought and flooding (ibid). Vulnerability of these districts is particularly felt when three consecutive flood incidents all over Kerala have had adverse effects on biodiversity, livelihood, and inhabitants' well-being (RGIDS, 2018)

SAPCC (2014) specifically identified Wayanad as one of the climate change hotspots in Kerala. It has been common in the district; flood during monsoon and prolonged dry spells in farm fields causes drinking water shortages. Wayanad is one of the poorest districts designated by the Ministry of Minority Affairs. It has the state's most prominent tribal population, accounting for 18% of the Scheduled Tribe (ST) population (District Census report, 2011), with livelihoods derived primarily from high climate-sensitive agriculture allied activities. The social and economic backwardness of the district makes it least able to adapt to climate change.

Along with the social and economic backwardness, high geographical fragility and irregular seasonal climate changes, farmers in Palakkad and Wayanad resort to coping adaptation strategies. These strategies include changes in cropping pattern, lift irrigation, mixed farming, use of early warning system, flood- and drought-resistant crop varieties, summer plaguing, inter-change between direct sowing and transplantation, continuous cropping, early maturing verities, delayed sowing, diversification to non-farm activities, and conversion to tree crops to increase the farm output (Author et al, 2021).

Palakkad district of Kerala was selected as the second study area. Palakkad has the largest production and area under paddy cultivation among 14 districts of Kerala. Palakkad has a higher concentration of scheduled caste population with livelihood derived primarily from high climate-sensitive agriculture and allied activities. Within the Palakkad district, Kuzhalmannam and Alathur community development blocs with the largest paddy area and production concentration were selected as study areas.

The vulnerability of Wayanad and Palakkad agriculture to climatic extremes is visibly perceived, particularly in paddy production. For instance, because of its physiographic feature of being lying in a low land area, 40% of the paddy cultivation of Wayanad concentrated in the Panamaram community development block is drowned in the unprecedented flood incidents. Therefore, Panamaram Community Development Block was selected to collect primary data. The field survey was conducted in September, October, and November 2019.

1.5.8 Sampling Procedure

The study used primary data collected from a sample of 330 paddy farmers from the Wayanad and Palakkad study areas. For the collection of 330 samples, the study adopted multi-stage random sampling.

In the first stage, out of the 14 districts from Kerala state, the two most vulnerable districts to climate change, such as Wayanad and Palakkad, is selected as the study area. From both districts, three blocks were identified and ranked according to the area under paddy cultivation---accordingly, one community development block from Wayanad and two community development blocks from Palakkad were selected based on being the largest area under paddy cultivation.

In the second stage, three blocks, one from Wayanad and two from Palakkad, are identified according to the largest area under paddy cultivation. Accordingly, Pnamaram CDB from Wayanad district and Kuzhalmannam and Alathur Block of Palakkad district are selected.

In the third stage, from all 15-gram panchayats of Kuzhalmannam and Alathur Block of Palakkad study area, 12 to 13 samples per gram panchayats, which make a total of 192 random samples were collected. For the Wayanad study area, from all 5-gram panchayath of Panamaram Block, 28 to 27 samples per gram panchayats ---making a total of 138 samples, were collected.

Pretested and structured questionnaire were used for data collection. Qualitative and quantitative data variables and questions pertained to socioeconomic characteristics of paddy farmers' households, various input costs, paddy outputs, formal and informal sources of credit to farmers, among others, were included in the questionnaire. Moreover, an open-ended question seeking farmers' perception of climate change, the adaptation and coping strategies employed in farming, was also included in the questions.

1.6 Scheme of the Dissertation

The **FIRST** chapter is the introduction. This chapter incorporates a brief theoretical background, gaps in the current knowledge about agriculture sustainability in the context of climate change, and the significance of the study. The methodology part of the present study consists of analytical tools used, concepts, and theory in connection with technical efficiency in climate change, an empirical model, data collection procedure adopted, study area selection, are discussed in this chapter.

The **SECOND** chapter deals with the literature reviews. The review covers different contexts of sustainable agriculture and focuses on climate risks since likely future impacts of climate change have become an important area of concern for agricultural sustainability. Various indicators for assessing agricultural sustainability are carefully extracted from the literature review, providing theoretical insights for the present thesis. The review has been classified into a theoretical review of agriculture sustainability, and subsequently, indicator-based review, and empirical studies on technical efficiency and climate change.

The **THIRD** chapter analyses the first objective of the study. This chapter analyses the performance of paddy farming in Kerala. The status of paddy production in Kerala compared to Wayanad and Palakkad districts and, finally, the technical efficiency of paddy cultivation from 2000 to 2018 is also analysed in this chapter.

The **FOURTH** chapter looked into the changing context of paddy cultivation Wayanad and Palakkad. In this chapter, demographic and work participation changes, the impact of land use and cropping pattern changes in paddy cultivation, technological and institutional support for paddy cultivation in climate change, and the impact of climatic variability in yield response on paddy output are discussed for the study area of Wayanad and Palakkad.

The **FIFTH** chapter is based on cross-section data where “technical efficiency effects of coping strategies and adaptation practices” are analysed and compared for the two districts of Wayanad and Palakkad of Kerala.

The **FINAL** chapter contains a summary, conclusion, and policy recommendation for sustainable agriculture in the era of climate change. It also gives direction for future research and limitations of the current research.

1.7 Limitation of the Study

This study deals with agricultural sustainability in the context of climate change. The concept of agricultural sustainability is multi-dimensional and involves a complex interaction among its components, such as economic, social, and environmental. The present study's operational definition of agricultural sustainability is limited by climate change and contextual and locational specificity of factors. Hence, agricultural sustainability is looked at only through the prism of regional-specific indicators where economic and environmental components put more weight. The concept of adaptation and coping strategies is more comprehensive and operates beyond the context of climate change consideration; the present study concentrated on those adaptation and coping strategies adopted by the paddy farmers specific to climate change adjustment. Since time series data for adaptation and coping strategies are not available, the study resorts to qualitative data where multiple responses of the respondents' have been employed to extract variables for adaptation and coping strategies. The scaling techniques with more comprehensive coverages and weighting to capture more and more accuracy in the variable used for adaptation practices and coping strategies may be considered for further study in this area.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

There has been a rapid growth of literature on sustainable development, particularly after the inception of the “United Nations Commission of Sustainable Development” since the 1980s. During this period, the issue of climate change received more comprehensive coverage in public thought through the evidence related to climate change (Leal, 2015). Although the concept of sustainable agriculture covers different contexts, this review focuses on climate change as it is an important area of agricultural sustainability. The review has been classified into five sections. The **first section** is a theoretical review of agriculture sustainability. In the **second section**, the indicator-based review has been done. The **third section** reviewed empirical studies of agricultural Sustainability concerning Indian and Kerala agriculture. The **fourth section** reviewed the empirical literature on the role of “climate change adaptation” practices on the “technical efficiency” of agriculture. The literature that used stochastic frontier analysis to analyze farm efficiency when farmers adapt to climate change is only included in the present review. Reviews using the stochastic frontier analysis methods except in the context of farmers' “adaptation to climate change” are beyond the present review's scope. The **fifth section** reviewed challenges of paddy cultivation in context of Kerala, Wayanad and Palakkad.

2.2 Theoretical Review

The concept of sustainability is open to diverse interpretations (OEDC 1999). Since sustainability is a contested and complex concept, a precise definition is impossible (Pretty, 1995). Although there is no agreement among scholars about the precise and absolute meaning of sustainability (ibid) with reference to agriculture (Hayati et al., 2010), there is broad consensus among scholars about the “three dimensions of economic, social, and environmental” components of agriculture “sustainability”. There has been a great attempt at defining agricultural sustainability since the Brundtland report on sustainable development, more or less in a similar fashion as the original definition.[4] However, Pretty (1995) says that each of these different versions is subtle; each emphasizes different values, priorities, and goals.

Hanson (1996) argues that sustainable agriculture as a concept gained prominence when the issue of impacts of agriculture emerged. These issues include "depletion of non-renewable resources, soil degradation, health and environmental effects of agricultural chemicals, inequity, declining rural community, loss of traditional agrarian values, food quality, farmworker safety, a decline in self-sufficiency, decreasing number and increasing size of the farms", declining land holdings, ecological degradation, energy constraints, water availability, etc. However, perceiving agriculture sustainability is equally crucial against such impacts as climate change. Among threats, the issue of climatic risks and uncertainty in influencing agriculture sustainability has been rarely addressed in sustainability studies.

Lowrance et al. (1986), in their work on "hierarchical approach to sustainable agriculture", propose a hierarchical definition of sustainable agriculture. In their study, "hierarchical systems are families of sub-systems arranged hierarchically". In other words, "a distinction at one level may be a stabilizing force at another; this state of affairs demands the use of the appropriate scales, only one of which will apply for a unified model of a given level of organization." They argue that there are critical sustainability constraints at different agricultural hierarchy scales---agronomic, microeconomic, ecological, and macroeconomic.[5] The paper argues that the relationship between different scales of hierarchy has a vital role in influencing agricultural sustainability. For example, actions and decisions are taken at one level of spatial or temporal hierarchy influence another level of hierarchy positively or negatively.[6] The study ends by suggesting that

[4] The original definition can be found in the Brundtland report on sustainable development: "sustainable development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs." This definition of sustainable development is based on intergenerational equity and considers the adverse effects of development activities.

[5] Agronomic sustainability means that a track of land maintains its productivity over a while. Ecological sustainability is the "maintenance of support systems provided by the non-agricultural and non-industrial segments of the region. Microeconomic sustainability depends on the ability of the farm as the basic economic unit". Lastly, macroeconomic sustainability is at the district, state, national and international level (Lowrance) et al., (1986)

[6] For instance, the agriculture-clean development mechanism provides a profitable option for Indian farmers to reap revenues from carbon credits and provides an environmentally benign option in dealing

agricultural "sustainability can best be addressed by recognizing the dominance of agronomic constraints at field scale, micro-economic constraints at the farm scale, ecological constraints at the landscape or watershed scale, and macroeconomic constraints at the national and international scale".

Pretty (2008) discusses the "concept, meaning, principles, and evidence of agricultural sustainability". According to him, agricultural sustainability is about "developing technologies and practices that do not have adverse effects on the farming environment, are accessible and effective for farmers, and can maintain agricultural productivity over a long period". Pretty's study put forward a new approach to agricultural sustainability that can apply to the farming system to check whether, with that approach, that farming system runs sustainably. However, practical difficulties exist in measuring and monitoring such a sustainable system. The approach is that,

> …farming system should integrate biological and ecological processes into food production, reduce the use of costly external inputs and non-renewable resources, causes no harm to the environment, the health of the farmers and consumers, make productive use of knowledge and skill of the farmers in order to replace human capital for costly external input, make productive use of the farmers collective capacity to work together get out of common agricultural and natural resources problem regarding pest, watershed, irrigation, and credit management etc.

He argues that adopting these principles in any farming system helps to build essential capital assets in an agricultural system, "such as natural, social, physical, and finance capital". However, operationalizing this approach to agriculture sustainability is a rather difficult task; nevertheless, the proposed underlying principle covers the three fundamental pillars of sustainability.

In his study, Pretty (2008) further analyses various characteristics of agriculture sustainability. "Sustainability does not mean ruling out technologies and practices on the ideological ground". If technologies do not produce undue harm to the environment and instead help improve farmers' productivity, then such a move "is likely to have some sustainability benefits". Therefore, a system can be identified as high in sustainability if

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with their agriculture residues (Reference available at http://greencleanguide.com/2011/09/13/cdm-and-agriculture/).

it "aims to make the best use of environmental goods and services without damaging its assists."

Another characteristic of sustainable agriculture is that such a system positively affects “natural, social, and human capital, while an unsustainable one does have feedback to deplete these assets, leaving fewer for future generations”. Therefore, all those activities that improve these renewable capital assets contribute to sustainable agriculture. Pretty (2008) in his “ways to maintain and enhance food production” identified that “neglect of both multi-functionality aspects of agriculture and considerable external costs poses the most significant challenges of agriculture sustainability for all developed and developing countries”. Moreover, “the multi-functionality nature of the agriculture system makes sustainability a relative and case-dependent concept. More sustainable agriculture seeks to make the best use of nature's goods and services. Technologies and practices must be locally adapted and fitted to the place”.

An agriculture system with a high level of “social and human assets” can innovate “more in the face of uncertainty”. Therefore, Pretty (2008) introduces a concept called 'sustainable intensification,' which implies better “use of existing resources and technologies and intensified use of natural, social, and human capital assets combined with the use of available technologies and inputs that minimize or eliminate harms to the environment”. He introduced this concept in contrast to the broad notion of extensive farming under its erroneous assumption that sustainable agriculture is based on net reduction in input use.

The sustainability of agriculture can also be studied with the help of both positive and negative externalities (Pretty 2008, Van Den 2010). Hence, agriculture sustainability is thus a matter of judgment that depends on comparators and baseline chosen. However, Pretty (2008) mostly tries to see agriculture sustainability from the perspectives of negative externality, which has four features: first, the “costs are often neglected; second, they often occur with a time lag; third, they often damage groups whose interests are not well represented in the political and decision-making processes; and lastly, the identity of the sources of externality is not always known”. The presence of sustainability can also be perceived through positive externality (Van Den 2010). However, “what has become clear in recent years from the modern intensive agriculture” around the globe is the success of modern agriculture that has greatly hidden the high environmental and health cost, which are the apparent signs of lack of sustainability of an agricultural production system.

In their work, Hanson et al. (1996) present a framework for characterizing the sustainability of a farming system by “defining sustainability as an ability of a system to continue into the future”. The study, to assess sustainability, adopts probability concepts that explain either success or failure of a farm system. The author reviews some of the earlier determinants of sustainability and his criterion of the minimum required level of livelihood goal. Hamblin (Hanson quoted, 1996) suggests declining production below the subsistence level for substance economy and below the profitability level for cash economy as the criteria for success or failure of a farm system. Lynam et al. (Hanson quoted, 1996) propose famine as the ultimate sustainability indicator. “Failure can be expressed in several other forms such as farm abonnement, the need to supplement income with off-farm employment, inability to meet critical goals such as education for children”, conversion of land to non-agriculture use, and significant changes of farm enterprises, among others (Hanson, 1996). The author strongly favours that the unit of sustainability assessment be at the farm level because it is the level where farmers implement and manage things “to meet the societal needs of food and other products requirement while protecting natural resources”. Moreover, the farming system being “dynamic, stochastic, and purposeful system”, characterizing “sustainability at the farm level” is much easy where system goal can easily specify than the other systems of farm hierarchy. While commenting appropriate time frame for assessing sustainability, the author supported 15-20 years is necessary to identify and detect significant threats to sustainability.

Hanson (1996), while examining “conceptual and methodological barriers to using sustainability” as criteria “for guiding” changes in agriculture, put forward two interpretations with two different underlying goals of agriculture sustainability. First, sustainability is “an approach to agriculture that is developed in response to the impacts of agriculture with motivating adherence to particular ideologies and practices as its goals”. The other one is sustainability as a property of agriculture developed in response to threats to agriculture to use “it as a criterion for guiding agriculture as it responds to changes". Moreover, he argues that agricultural sustainability is useful only for motivating changes. However, "the usefulness of this interpretation as criteria for guiding changes is hindered by the lack of generality of the prescribed approach[7], distorted view about conventional agriculture,[8] and circular logic"[9]. Therefore, Hanson argues it would be more consistent if agricultural sustainability were interpreted as a system property.[10] According to Smith et al. (1998), the advantage of perceiving sustainability as a system property "is that it captures a multi-objective character of sustainability". However, care must be taken while specifying different goals according to the context-specific definition of sustainability. Hence, for that goal, Hansen (1996) recommends that the "elements necessary for approaches to characterizing sustainability" in the agriculture system should be "literal, system-oriented, quantitative, predictive, stochastic, and diagnostic".

Pretty (1995) works on 'participatory learning for sustainable agriculture,' consisting of two parts. Firstly, agriculture should have the features of persistence and resilience. Persistence is the capacity of agriculture to continue for a long time, whereas resilience "implies the ability to bounce back after unexpected difficulties". The second part is about the environment in which practices and technologies should not degrade or damage the very base of agriculture upon which it depends. Moreover, agriculture sustainability in the context of climatic risks implies that it should have persistence and resilience, where later denotes the adaptation capacities to fulfil the agriculture sustainability. However, there is a wide variation in the interpretation because conditions and assumptions under which agriculture sustainability occur differ hugely. Therefore, the treatment of

[7] Agricultural sustainability was primarily developed in response to the problems of specific countries of the developed world, such as Europe and the US. In contrast to conventional agriculture in developed countries, the alternative agriculture movement has different circumstances and problems. Strategies towards sustainability in less developed countries are therefore "hindered by a lack of generality of the approach"

[8] Distorted caricature of conventional agriculture implies that those practices in conventional agriculture are sustainable in some senses are rejected due to their link with conventional agriculture.

[9] Circular logic is the reason by which the sustainability approach is not helpful in guiding changes in agriculture. A particular approach is applied in a particular context, and their contribution as an approach cannot be used in another context due to circular logic. According to Smith et al. (1998), it means "it is based on some presumed benefits of listed practices but does not provide any quantitative analyses, for instance, that using fewer chemical is better."

[10] "As a property of agriculture, sustainability is interpreted as an ability to satisfy diverse goals" and continue through time.

sustainability in the context of climate change requires entirely different considerations among different components of sustainability.

Webster (1997), while assessing the economic consequences of sustainability regarding European agriculture, argues that a shift toward sustainable agriculture stems from the argument that presents an undesirable state of the environment in economic, social, and ecological sense and hence, there is a gradual decline in the utility to whole members of the society. The author argues that social problems arise because fewer people are employed in agriculture, though prominent people reside in rural areas, nevertheless less to do with agriculture. Those who remain in agriculture are socially isolated and suffer hugely due to declining rural social services. The economic problem arises because of a gradual decline of the supported nature of agriculture with the decline of income relative to the other sectors of the economy. Ecological issues arise due to pollution of various kinds, such as excessive chemical fertilizers and pesticides, herbicides, fungicides, and disposal of natural wastes from livestock rearing. However, the conditions and assumptions of agriculture sustainability vary when one considers the agriculture sector of developing countries like India, where many people who inhabit rural areas have to rely on agriculture for their livelihood. Less diversification potential away from agriculture in income and employment generation results in deep-rooted distress. Climate change, declining holding size, land degradation, and lack of interest in farming threaten Indian agriculture (Praveeen et al., 2013). The agriculture sector in developed countries is assumed to be relatively more sustainable during climatic stress and variability due to good adaptive capacities than developing countries with poor adaptation capacities. Hence, agricultural sustainability may be adversely affected in response to threats of the above kinds.

Pretty et al. (1993), while studying recent achievements and new policy challenges for sustainable agriculture, put forward five defined agricultural sustainability goals. These are the incorporation of the natural process into the agricultural production process, minimization of the use of off-farm inputs with maximization of dependence on internal inputs, extensive use of the genetic and biological potential of animal and plant species, increase in the compatibility between cropping patterns and current production level, and lastly, “profitable, whole-farm management to conserve soil, waste, energy and biological resources". However, the social dimension in the context of threats and uncertainty for its goal towards agriculture sustainability is missed out, and the requirement of the same is assumed to be a prerequisite. For example, Roy et al. (2012) argue that social self-sufficiency enables farmers to participate in local organizations, sharing information, knowledge, skill, and experiences about climate-adjusted farming practices.

Pretty et al. (2003) "examined the extent to which the farmers have improved food production" in recent years with low cost, locally available, and environmentally sensitive practices and technologies. They argue that improvement in food production occurs through four mechanisms: intensification of single components of the farm system, the addition of new productive elements to a farm system, better use of land and water to increase crop intensity, and improvement in per-hectare yield of grains through the introduction of new regenerative elements into the farm system and new locally appropriate crop verities and animal breeds. The study argues that the improvement noted in agriculture results from adopting practices and technologies in agriculture, leading to "increased water use efficiency, improved soil health, fertility, and pest control with minimal or zero pesticide use". However, when system tradeoffs among components are not explicitly taken into account in the study, for instance, expansion and intensification inevitably result in biodiversity loss or habitat decline, in turn causing a reduction in productivity in the long term.

Thompson (1992), in his philosophical discourse on agricultural sustainability, argues that "although there are a lot of distinctive methodologies for measuring and pursuing sustainability through technical research", one should approach two different ways in their attempt to conceptualize agricultural sustainability. Firstly, a problem of resource sufficiency implies measuring production and consumption that may deplete resources or measuring available stocks of those resources. Finally, relative sustainability is "determined by predicting how long the practices may be continued given the existing stocks of resources. Secondly, conceptualizing in terms of functional integrity of a regenerating system".

> … In this view, practices that create a threat to the system's capacity for reproducing itself over time is said to be sustainable. These approaches require an

account of the system in question that specifies its reproductive mechanism as well as an account of how specific practices places those mechanisms at risk.

Based on these two approaches, on the one hand, one can see the functional integrity among the components of agricultural sustainability in a more compatible manner, and on the other hand, what happens to the relations among different parts when there occur climatic shifts or variability and sometimes even extremes like floods and droughts. In both cases, how the system gets worsened due to climatic variability and destruction of the environment stems from unhealthy agricultural practices needs to be analyzed.

There are two ways by which one can approach agricultural Sustainability (Thompson 1992). The "goal-prescribing concept interprets sustainability" in terms of "ideological or management approach to agriculture, developed in response to" concern about the "negative impacts of agriculture with an underlying goal of motivating the adoption of an alternative approach and secondly-system describing concept- interpret sustainability either as an ability to fulfil a diverse set of goal or as an ability to continue". However, Hanson (1995) classified different approaches to agricultural sustainability based on "ideology, set of strategies, ability to fulfil a set of goals, and ability to continue in the future". When one comes close to the studies based on these approaches, understand that each of these different variant approaches tries to analyze agricultural sustainability based on the premises of indicator system, which fulfils the required sustainability goals mostly impacts-based studies. However, Thompson's (1992) two conception, system describing concept reveals considerable importance because Hanson (1995) views the concept has the potential to describe concern about the threats to agriculture and "using sustainability as a criterion for guiding agriculture as it responds to rapid change in its physical, social and economic environment". Therefore, in the context of likely future impacts of climate change, the system describing the concept of sustainability reveals considerable importance because the agriculture production system expects to face sustainability threats.

Hua (2007) argues that foreign scholars cannot accept the exiting domestic sustainability evaluation method, and their scientific base is inadequate. While analyzing problems of the previous studies on the indicator selection and evaluation, the author put forward the farmer development index. In order "to reflect the significance of different indicators when their values are changing", studies proposed a "dynamic weight calculation method". However, both these methods were found to follow the same previous techniques of incorporating indicators of different components of agricultural sustainability with the variant in different contexts and systems. Hence there is a replication of previous wisdom about the indicators. This is what Hanson (1996) called the result of circular logic. Therefore, interpreting Sustainability is not a useful criterion for guiding changes in agriculture. There is also a need for great caution for those measures of sustainability because the subjectivity of the "content of the indicator system is different for each farm for different countries, regions, and development stages".

Smith et al. (1998) reviewed the current state of knowledge regarding agricultural sustainability in the broader background of sustainable development. While proposing a framework for assessing agricultural sustainability, they suggest adopting a multi-scale approach because spatial and temporal features influence agricultural sustainability at different scales. The factors that hinder progress towards agricultural sustainability are the techniques employed in the framework rather than identifying all factors that affect agricultural sustainability. However, identifying particular factors that hinder progress towards sustainability is limited in scope because it cannot bring forward the relationship between enabling and disabling factors together in the analyses. For instance, fertilizer, pesticides, and poor tillage practices are the hindering factors of sustainability; however, a decline of the same equally leading to a shift away from sustainability cannot be separated in another sense. Hence system tradeoff will result. Therefore, one needs to consider enabling and disabling factors that lead to sustainability and unsustainability to moderate system tradeoffs.

Smith et al. (1998) reviewed a large body of literature focusing on agricultural sustainability assessment concerning different conceptual approaches. They are 1. Adherence to prescribed approaches, 2. Based on multiple qualitative and quantitative indicators, 3. Time trends 4. Resilience and sensitivity analyses and lastly 5. System simulation model. Assessing sustainability based on adherence to particular approaches is the same as Hansen's (1996) conception of interpreting sustainability as an approach to agriculture, such as farming system classified as sustainable if it introduces practices of minimizing the use of chemical inputs, reducing fossil fuel consumption, incorporates rotation and multiple cropping, including nitrogen-fixing legumes, minimal tillage and adding cover crops. However, this approach has the problem of lack of generalization. For example, prescribed practices deemed sustainable in one situation may not be in another.

Another way of assessing sustainability is based on multiple qualitative and quantitative indicators consistent with Hanson's (1996) concept of interpreting sustainability as a system property.[11] In this approach, several systems attribute influence sustainability, measurable indicators are identified for each attribute, and a negative trend or change in a single indicator represents a lack of sustainability. All of these multiple qualitative or quantitative approaches have an issue of diagnosing the threats to agriculture, although the prescribed approaches are developed in response to threats to agriculture.

According to Smith et al. (1998), the third way of assessing agricultural sustainability is based on time trend analyses that fulfil the ability of a system to continue through time. This aspect is consistent with Hansen's (1996) concept of the literal meaning of characterizing agricultural sustainability, i.e., the system has to have the capacity of persistence despite disturbances if it is to be sustainable for an extended period. Monteith (1990) proposes a contingency table to assess the non-negative trends in selected system properties that indicate sustainability.

Resilience and sensitivity analyses are another way to assess agriculture sustainability, which system can maintain its productivity in response to stresses of various kinds, presumably climatic stress in this study. Therefore, the ability of a system to have its resilience depends on the adaptability of agriculture, which could also contribute to sustainability. For Smith et al. (1998), resilience and sensitivity can be considered as an aggregate system response to the determinant of sustainability. It is assumed that agriculture as a system is said to be sustainable in the context of greater threats of climate change and others if it has greater resilience and a lesser level of sensitivity.[12]

[11] "Sustainability is interpreted as an ability to satisfy diverse set goals" where no single indicator exists.
[12] Resilience implies a level of stability in such a way as to make adaptive capacity and self-organization property or the capacity of a system to respond to changes. In other words, it may denote preservation of the behaviour of the system as expressed by its states remaining within the considered domain of attraction (Gallopian, 2006).

2.3 Indicator-Based Review

This section reviews the methodologies adopted to assess agricultural sustainability in general. Literature that deals with systemic and components specific indicators to fit into the context of agricultural sustainability, particularly relevant to climatic risks, is reviewed.

Broadly, there are three components of agricultural sustainability: economic, social, and ecological. Different scientists have proposed various indicators for agricultural sustainability by classifying them under three different components. Environment, development and economic literature try to develop agricultural sustainability indicators covering three social, economic, and environmental pillars, making the study more or less interdisciplinary. The entire indicators of agricultural sustainability can be classified as either under trend indicators or state indicators.[13] Walker (2002) says that trend indicators delineate the long-term behaviour of a particular indicator variable under consideration for sustainability assessment, whereas state indicators picturesque perception about the past and present behaviour of variable indicator and indication towards what ought to be the future state of the system. However, there are other ways by which indicators can be looked. The OECD (1999) definition of indicator selection, i.e., "Driving-Force-State-Response framework", where "driving forces are those elements that cause changes in the state of the" agriculture environment, "the state or condition of the environment in agriculture refers to changes in environmental conditions that may arise from various driving forces, and responses refer to the reaction by groups in society and policymakers to the actual and perceived changes in the state of the environment in agriculture, the agriculture sustainability, and market signals".

Sustainability evaluation based on the indicators set represents the most widely used approach in the literature. Indicator-based approaches are conceptually consistent with

[13] Condition indicators imply states of the system relatives to the desired state or that can explain the present conditions of the environment. Trent indicators can be used to measure how the system has changed or monitor trends in condition over time. Trend indicators detect historical development or the sudden past shift, Michael A. Zöbisch (2007).

sustainability as a system property and methodologically appropriate to the multiple qualitative and quantitative indicators of a system (Smith et al., 1998). Indicators to assess agricultural sustainability vary because of the involvement of fundamental site-specific heterogeneity and dynamism of different contexts of agriculture (Ikerd, 1993). Sustainable agriculture also depends on the perspective of the analyses (Webster 1999). Agriculture sustainability is a "social construct," and hence, measurement is a difficult task (Simon et al., 1999). Therefore, in the context of climate change, Pretty's (1995) explanation reveals considerable importance. He argues that when specific parameters or criteria are selected, one who assesses agriculture sustainability in any context can "say whether certain trends are steady, going down or down going up". Nevertheless, from an economic perspective (Smith et al., 1998) argues "that profitability indicators such as total production and net farm income are the primary indicators of agricultural sustainability".

Roy et al. (2012) assess agricultural sustainability indicators. With regards to agriculture, sustainable development means

> …an activity that permanently satisfies a given set of conditions for an indefinite period of time that are highly congruent to the multidimensional attributes inherent in the concept of sustainable development, highlighting ecological stability, economic viability, and a socially fair agricultural system.

The indicators have been classified under three separate components.

Roy et al. (2012) state that "sustainable agriculture is a time- and space-specific concept, existing development and critical analyses of indicators are not case-sensitive and demand lead in the context of climate change and intensification of agriculture." Therefore, the study proposed that agricultural sustainability indicators, including "net farm return, land productivity, crop diversity, and sufficiency of cash flow", are categorized under the "**economic indicators"** of agricultural sustainability. Under the social dimension, the selected indicators are "education, input self-sufficiency, and social involvement". "Integrated water management, integrated nutrient management, integrated pest management, soil quality status, soil fertility management, and biodiversity are included under the ecological dimension" of agricultural sustainability. These indicators "assess the particular social, economic, or environmental condition" that has its own relationship with sustainable agricultural practices. However, the extent to which indicators are linked with climate change and variability is far from the studies. Therefore, one has to incorporate adaptive capacity or resilience indicators in the sustainability indexes to reflect upon the influence of those variables in determining sustainability.

The farming system is **economically sustainable** if it remains profitable without taking an economic risk. The most important indicator used to assess profitability is net farm return, and it indicates the viability of the farming system in an economic sense. “Total Factor Productivity” (TFP) “refers to the output per unit of input used and is expressed as a benefit-and-cost ratio”. “The physical yield of crops” measures land productivity. “Crop diversity increases farm productivity and reduces the variability of agricultural income. Sufficient “cash flow covers operational expenses on time” (Roy et al., 2012).

Smith et al. (1998) have chosen “production cost, product prices, and net farm income” under economic indicators of agricultural sustainability. The authors include “access to resources, skills, knowledge, and planning capacity of farmers, awareness” under social indicators of agricultural sustainability, whereas “land capacity, nutrient balance, biological activity, soil erosion, fertilizer use” under environmental dimention.

Suzanne et al. (2011) conceptualize **social sustainability**. They put forward a three-fold “schema of social sustainability”:

“Development sustainability - addressing basic needs, the creation of social capital, justice, and equity”;

“Bridge sustainability - concerning the changes in the behaviour to achieve bio-physical environmental goals”;

“Maintenance sustainability refers to preserving what can be sustained of socio-cultural characterizing in the face of change and ways in which people's activity embraces to resist those changes”.

Roy et al. (2012) maintain that social sustainability is the farmers' capacity “to tackle certain circumstances” and hence use “input self-sufficiency to measure farmers' ability to fulfil internal extraction of inputs” rather than depending on external inputs. Another indicator is “farmer social involvement in local organizations, enabling farmers to share information, knowledge, and skills”. Therefore, education can be conceived as the crucial indicator for measuring the social sustainability of agriculture. A socially sustainable farming system “accelerates farmers' collective capacity to work together to solve common agricultural and natural resource problems regarding pests, weeds, diseases, watersheds, irrigation, and credit management problems” (Pretty, 2008).

Environmental indicators are considered to be prime assessors of agricultural sustainability. The indicators identified to look into the ecological aspects of agricultural sustainability are integrated water management which measures the irrigation problem of rain-fed agriculture. Depletion of the water table, salinization, waterlogging, etc., indicate unsustainable farming in an ecological sense. Integrated soil management is another indicator of soil erosion problems due to unhealthy tillage practices and soil conservation through organic means. “Soil health is universal for sustainable agriculture, and this can be achieved by adequately maintaining the broad aspects of agriculture such as fertilizer, nutrients, disease, pest management” ……..(Roy et al., 2012).

Some studies emphasize “bio-physical and socio-economic conditions of the study areas as primary criteria for selecting agriculture sustainability indicators” (Roy, et al., 2012). Depending on the sustainability goal, site-specific and case-specific factors influence indicator selection. The sustainability goal of agriculture in response to threats---climate change is the case here---requires that one give greater weight on environmental dimensions of and indicator and other dimensions. One such study can be found in Zhen et al. (2003), proposing agricultural indicators to measure sustainability. It is assumed that the adaptive capacity of agriculture to climate change determines agriculture sustainability in the context of climate change. However, “the adaptive capacity of agriculture to climate change depends on socio-economic factors and vulnerability to change” (Adger et al., 2004). Moreover, adaptive measures have to be designed in such a manner to fulfil the principle of sustainable agriculture.

2.4 Empirical Review of Indian Agriculture Productivity and Sustainability

This section is devoted to reviewing empirical literature concerning Indian agriculture sustainability. It has been found enormous in the literature that sustainability has been approached through the long-term trend in agriculture productivity at the aggregate national, state, and district levels. Therefore, the literature dealing with the nature of agriculture growth in India and productivity in general and sustainability, in particular, have been incorporated in the review.

Mohan (1974) attempted to estimate the contribution of research and extension to productivity change in Indian agriculture from 1952-53 to 1970-71. The study was conducted with a particular focus on seven states where the Intensive Agriculture Districts Programme was initially implemented as a green revolution technology. The TFP approach was employed to check the effects of research and extension on agriculture productivity. The study found that total productivity gains in Indian agriculture have been extraordinary, although more significant regional disparity exists among states under study. The study also found that the Indian agriculture research system and its indirect impacts upon other development activities have been the significant determinants of productivity change in Indian agriculture.

Regarding the post-green revolution in Panjab state, Sidhu et al. (1991) seek to analyze the technical change in wheat productivity using the TFP approach. The study estimates trends in output and input, output and input prices, cost structure, and the technical change in wheat production from 1972 to 1987. The study found that the prices have declined for the most input between 1971 and 1987. Fertilizer price, the real wage of labourers, and the real price of wheat declined significantly due to technical change from which consumers and producers equally benefited. The study found that the most important sources of productivity increase are labour-saving technologies such as tractors and other machines. The study concludes that a significant decline in input index is reflected in an increase in wheat yield, which correlates with the overall TFP improvement at 1.7% annually during the period under study.

Rosegrant et al. (1992) assess India's TFP growth, using the Tornquist-Theil index for district-level crop sector from 1956 to 1987. The study estimates the sources of TFP growth and the rate of return to public investment in research and extension. The TFP index has been regressed for 15 variables indicating “investments in research, extension, human capital, and infrastructure” to deconstruct the sources of growth. The model also includes dummy variables for agro-climatic zones. The study found that public and private research and extension expenditures significantly impact total productivity. The "stock of research, extension expenditure, domestic and foreign inventions on agriculture implements, and adoption of modern varieties have statistically significant" and positive impacts on TFP. The study concludes that the "rate of return to public research and extension is high shows continued productivity of public investment in agriculture research and extension".

Ninan et al. (1993) analyze the "growth experience of Indian agriculture and its implication for growth equity and sustainability" against the background of "green revolution and dryland agriculture using crop-wise disaggregated time series data". The study also examines the "association between growth and instability and the factors behind yield instability". The study then looks at "the cost economies of Indian agriculture", which covers many crops and regions. The study found that "irrigated crops and access to modern farm technology have dominated the growth process". Dry and drought-prone regions have also shared the gain of agricultural growth. However, "this growth process has been accompanied by high instability in yield and an increasing cost of cultivation". Factors like climatic variability (rainfall), the extension of cultivation to marginal land and risky regions, widespread use of modern technologies and associated outbreak of pests and diseases, changes in the price policy environment, a transition from subsistence to commercialized agriculture, differential access to infrastructure and institution by the farmers, and environmental degradation have been identified as the drivers of yield instability in the growth process of Indian agriculture, and that affects sustainability adversely. The study concludes with the impacts of the dryland watershed development program, favorable impacts identified as growing additional crops, enhancing crop yields, and employment generation.

Dholakia et al. (1993) examine the growth of Indian agriculture over its three distinct phases, namely the "green revolution period" (from 1950-51 to 1966-67), "the initial phase of the green revolution" (from 1966-67 to 1980-81), and (c) "the modernization phase" (from 1980-81 onwards). The study's main objective is "to appreciate the role of agriculture in the acceleration of economic growth experienced in the 1980s in India". Therefore, the study covers the entire agriculture sector as a whole. The trend in total factor inputs and TFP growth of the agriculture sector is given greater emphasis. The study estimates “the sources of growth of Indian agriculture for the above sub-periods”. The study also estimates “the effects of adverse weather conditions and the intensity of resource use on TFP growth. A neoclassical growth accounting framework has been employed to measure the TFP index.

According to the study, the acceleration of agricultural growth is significantly influenced by TFP growth, facilitating the release of scarce resources for the other sectors of the economy. This phenomenon has an additional benefit as a driving force for the growth of the overall economic sector of the country. The determinants of TFP are expressed as the independent variables such as cropping intensity, irrigation, fertilizers, and high-yielding varieties of seeds. The multicollinearity among determinants of TFP has been adjusted using principal component techniques and is considered unavoidable for time series data. Principal components techniques support the hypotheses that modern agriculture input determines TFP corrected for the weather (ibid).

Kumar et al. (1994) assess “TFP growth in different regions of India and” examine “the sources of productivity growth” for the rice crop. The Divisia-Tornquist index computes “the total output, total input, and TFP indexes and input price indices for rice using farm-level data” from 1971-88 for 15 Indian states. “The authors examine the changes in input use, productivity, and cost of production, identify the potential regions for further productivity gains and suggest ways to increase rice productivity”. The “marginal rate of return to public investment in rice research” is also considered in the study. The estimated TFP for rice is 1.03%, accounting for about one-third of the output during 1971-88. According to the study, public research, market infrastructure development, and balanced fertilizer use have significantly accounted for the total productivity growth. The study also found a significant and high marginal rate of return to investment in rice-growing regions.

As part of an extension of an earlier study, Rosergrand et al. (1995) examined the “TFP growth and source of long-run growth in India”. Differences to the earlier study, this study tries “to assess the TFP growth, including private and public investment, and examine the rate of return to public investment in agriculture”. The methodology employed is the same as in the earlier study. However, to decompose the total productivity growth, independent variables in the regression equation are classified under three heads. The first is “the technology variable, which includes agricultural extension staffs per 1000 farms, agricultural research stocks (billion rupees), the proportion of crop area in modern verities, factor weighted domestic invention stock, factor weighted foreign invention stock”. The second is “the infrastructure institution variable, consisting of regulated markets, net irrigated area/net cultivated area, daily farm wages/annual non-farm earning, the proportion of rural adult males, and crop wholesale price/crop farm price”. The third are “other variables such as year, agro-climatic dummy variables, annual rainfall, June rainfall, and July-August rainfall”. Furthermore, the decomposition of TFP growth for the crop sector in India is examined for the three sub-periods, namely the pre-green revolution periods (1956-66), the early green revolution period (1967-1977), and the late green revolution period (1978-1987).

The study shows that the trend in TFP growth is relatively steady over time, with modest variation in growth rate but significant fluctuation due to weather variables. The severe drought years of 1965, 1966, and 1979 resulted in significant reductions in TFP growth. TFP growth accounts for half of the total output growth in the crop sector (1.13 per cent). The TFP decomposition equation's estimated parameters show that public research, extension spending, irrigation, and foreign private research have statistically significant and positive impacts on TFP over all periods. Research and extension together accounted for more than half of the TFP growth. The study concludes that the marginal rate of return of public research in agriculture is very high at more than 70% for all periods. Therefore, the study suggested that it is imperative that the Government of India profitably expands the current level of public investment in agriculture (ibid).

Desai et al. (1997) examined the determinants of TFP in Indian agriculture. Their paper developed a “comprehensive framework of price and non-price factors” for studying the determinants of TFP in Indian agriculture. Tornquist-Theil index of TFP from the translog production function was used to estimate the model. The study estimated a multivariate model of determinants of TFP in Indian agriculture for 1966-67 to 1989-90. Index of barter terms of trade with the base year 1980-81, “cumulative government expenditure on research and development, P_2O_5 to N fertiliser consumption ratio, the share of canal irrigated area land, rural literacy ratio, marketing and banking infrastructure, the density of rural roads, Gini ratio of owned land distributions, Gini ratio of operational land distributions and average annual rainfall" are the ten variable used in the model. The study reported that the "non-price factors are more important in inducing a technical change in Indian agriculture than price factors". An important finding of the study is that government expenditure on agriculture research and development, education, and extension constitute a single and prominent determinant of TFP. This variable alone explains as much as 87% of the total variation accounted for by the estimated model.

Kumar et al. (1998) studied the "sustainability of the rice-wheat"-based farming system in India with the help of the TFP approach. TFP has been estimated for the area under the rice-wheat-based "cropping system in the Indo-Gangetic plains" using the Divisia-Tornquist index approach. An important objective of the study is to assess "the sustainability of the rice-wheat-based cropping system in the Indo-Gangetic plains" and understand the critical role of the RWCS in contributing to the country's food security. The study also analysed the influence of legume crops in maintaining the sustainability of the cropping system. The critical question to the sustainability of the cereals production in general and the Indian agriculture sector, in particular, is that indiscriminate use of resource degrading inputs such as fertilisers, pesticides, and other inorganic manures has seriously undermined the TFP of the RWCS of the Info-Gangetic region over the years.

In a study of "Agricultural Research and Productivity Growth in India", Evenson et al. (1998) assess the effects of public and private investment in agriculture research, extension, and irrigation on the growth of TFP. The growth accounting approach is adopted in the study to cover five major food grain and 14 minor crops in 271 districts of 13 states for the period between 1956-57 and 1987-88. The study tries to examine the source of productivity growth and find that gains in agriculture productivity were highest during the early periods (1966-76) of the green revolution. However, productivity increases in every district in India, the highest gain in productivity is reported in rice and wheat-producing regions. The study also found that, during the green revolution mature period (1977-87), investment in research and development and extension in agriculture continued to impact TFP substantially. The study establishes that, since 1956, high-yielding varieties and conventional input together have contributed on an average of 2.3 % a year to crop production growth. Although "high-yielding varieties in wheat, rice, and other crops introduced in the 1960s have contributed to" the significant gain in TFP, they are not the only source of growth. Hence, the study argues that investment expenditure on research & development, extension, and infrastructure services constitute significant sources of total productivity growth. The study concludes with the suggestion for expanding public investment in research and extension in agriculture since the marginal internal rate of return to agriculture research has remained high for the study concerned.

Research on "linkages between agriculture spending, growth, and poverty in rural India" by Fan et al. (1999) explores the variables that have contributed to the reduction of rural poverty in India, with a focus on the role of government investment. The study's main goal is to determine the effectiveness of various types of government spending in alleviating poverty. The study employs state-level data to develop an econometric model that calculates the number of impoverished people lifted out of poverty for every million rupees spent on various spending items. The model is set up to determine the multiple channels through which several government spending influence the poor while differentiating direct and indirect effects.[14] The study argues that targeting government expenditure simply to reduce poverty is insufficient. The model's findings show "that government spending on productivity-enhancing investments like agricultural research and development, irrigation, rural infrastructure (including roads and electricity), and rural development targeted at the poor have all contributed to a reduction in rural poverty and must have also contributed to an increase in agricultural productivity". The study also discovered that government spending on roads had a considerable impact on poverty reduction and productivity growth. As a result, this method contributed to a dominant win-win situation.

[14] "Government investment in rural infrastructure, agriculture research, rural health, and rural education promoted agricultural and non-agricultural growth, resulting in more employment and income-earning options for the poor and cheaper food, which leads to indirect effects". "Benefits derived from employment programmes specifically targeted to the rural poor are the direct effects".

Furthermore, increased government research and extension funding has the most significant impact on agricultural productivity increases and provides numerous benefits to the rural poor. The study's policy implications are that instead of explicitly targeting rural development to eliminate poverty, the government should focus its spending on rural roads, research and extension, and other productivity-enhancing technology in agriculture. Increased government spending on rural development is an excellent approach to help the poor in the short term, but because it has minimal impact on agricultural output, it does not contribute much to a long-term solution to the poverty problem.

Rosegrant et al. (2000) studied “productivity growth and sustainability in post-green revolution agriculture in the Indian and Pakistan Punjab”. The study estimates trend in TFP for the production system in both states using the Tornquist-Theil chain-linked index approach for aggregation of output and inputs. The study period has been categorised into three: early phases of the green revolution (from 1966 to 1974), input intensification period (from 1975 to 1985), and post-green revolution period (from 1986 to 1994). This study tries “to quantitatively disaggregate productivity growth into the effects of technical change, education, infrastructure, and especially degradation in the quality of land water resources”. Therefore, “productivity growth is econometrically decomposed into the effects of technology, resource degradation, human resources, and degradation”. The study found that output growth and crop yield were higher in the Indian Punjab. However, productivity growth was higher with only a small margin. Resource degradation occurs due to the intensification of rice-wheat farming in Punjab, causing “reduced overall productivity growth from technical change and investment in education and infrastructure by one-third”. The study highlights “policy issues that affect agricultural productivity and sustainability”, where positive side factors like public investment in research and extension, education road, whereas input subsidies exacerbate resource degradation on the negative side.

Janaiah et al. (2005) try to address the empirical question of the productivity impacts of the green revolution technology in rice crops based on TFP analyses. The study argues that changes in physical yields are not an accurate measure of productivity. Therefore, the study addresses the TFP approach to measure technological impacts from efficiency perspectives. The Tornquist-Theil index is used to estimate state-level TFP for the two different periods, viz., early green revolution period (until 1985) and late green revolution period (after 1985). The study found that “various modern technologies adopted by farmers over the period have continued to considerably impact rice productivity growth, which is reflected in the increasing trend of TFP growth”. Further, the productivity impacts of the successive generation of modern technology have been reduced due to decelerated rate of TFP growth under the irrigated ecosystem during the late green revolution period.

Kumar et al. (2006) estimated the agricultural productivity trend state-wise and analysed the sustainability issue in Indian agriculture. The study looked at temporal and spatial variation in productivity “with reference to individual crops in recent years” and used the TFP estimate (Divisia-Tornqvist index). The study made a “strong perception that technological gains have not occurred in several crops, notably coarse cereals, pulses, oilseeds, fibres, sugarcane, and vegetables during the 1990s”. The study also finds that greater productivity attained in area and crops during the early green revolution period has not sustained further instead exhausted their potential. Although the study tried to address the agriculture sustainability issue, empirical evidence did not go beyond highlighting the declining trend in TFP of some individual crops. It also fails to propose valid reasons for the lack of sustainability.

Bhatia (2006) analyses the pattern of development and trends in productivity and the profitability of Indian agriculture to examine the requirement of agriculture sustainability. The study identifies that the agriculture sector's spectacular growth and tremendous development stem from improvement in total agricultural production and productivity during the 1960s to 1980s. The continuous deceleration in production and productivity since the later 1980s is because of either non-adoption or non-modification of acclaimed technologies. However, the deceleration of the agriculture sector since 1980 and the increasing disparity between the agriculture and non-agriculture sector can also be explained using other ways. The emerging economic conditions and trends in production and productivity fulfil only the economic dimension of agriculture sustainability. The question of sustainable development and other subsequent versions of sustainability become very apparent during the post-Stockholm conference in the 1980s. In the second half of the 1980s, the World conservation strategy and Brundtland commission on sustainable development increasingly made an enormous amount of awareness and consideration of environmental impacts of development on national development. Agriculture sustainability may be adversely affected by the development of unsustainable practices and other natural factors such as climatic variability and changes.

A study of data spanning from 1950 to 2000 shows that the trend in production and productivity of Indian agriculture shows a decline, particularly declining trends in profitability after the 1980s. Technological fatigue in agriculture, particularly after 1980, is the reason for the recent deceleration in growth in agriculture productivity and production. The study reported the presence of sustainability at an aggregate social level because per capita agriculture output was sufficient until the 1990s. However, from the 1990s onwards, production and productivity trends of major crops declined, even less than total population growth. Hence, during this period, the study argued that aggregate social sustainability in India declined for the first time after independence. Though the study raised the concern that agriculture sustainability is a multi-dimensional and multi-scaled concept, it did not bring sustainability issues from the perspective of an environmental dimension. Indian agriculture, where diversity and multiplicity of factors influence its performances, analysing sustainability against the context of emerging economic conditions and profitability of agriculture alone is not sufficient. Hence, this study may not meet the requirement of sustainable development in agriculture.

Kalirajan et al. (2006) “examine the sources of agricultural output growth in the pre-reform period”. The evaluation of agricultural growth performance is done using different approaches where input components of output are subtracted from technical efficiency and technical change; therefore, decomposition of output growth into an increase in output, increased input use, efficiency, and improvement in technology. State-level data used for the empirical study comprised 15 states from 1980 to 1990. The “results suggest that pre-reform farming performance was not impressive”; overall, there was a substantial diminishing performance in the contribution of TFP growth, which even broadly held for across states. The study also confirms that "pre-reform output growth increasingly stems from input growth. In short, the study concludes that between 1980-1990, Indian agriculture experienced a low rate of technological progress, together with gradual improvement in technical efficiency, but output growth in the sector increasingly stemmed from input growth".

Joshi et al. (2006) analyses "Sources of Agricultural Growth in India; Role of Diversification towards High-Value Crops". The study decomposed "crop income into the contributions of yield increase, area expansion, price rise, and diversification from low-value crops to high-value crops" using multiple methods developed by Minot (2003). The study verified the national finding that in the 1980s, the technology-driven high yield was the primary source of crop revenue, whereas, in the 1990s, rising prices and diversification toward high-value crops were the primary sources of agricultural growth. Diversification accounted for only 27 per cent of income increase in the 1980s. In the 1990s, however, the figure was 31%. According to the study, greater national average results obscure significant regional variances. Price rises were a significant source of growth in the northern and eastern regions, whereas higher sources of income growth were given by "agricultural diversification in favour of high-value crops" in the southern and western regions. The study's policy implications are that recovering grain yield increase will necessitate investment in agricultural research and development. Furthermore, institutional development is required to better connect small farmers with a burgeoning market for high-value commodities, allowing for further diversification.

Tripathi (2010) studied the TFP growth of Indian agriculture. The study examined the performance of agriculture productivity in India for 37 years, from 1969 to 2005. Based on time-series data from 1969-70 to 2005-07, the study constructed a TFP index based on Cobb Douglas's production function approach. Despite the limitation of the partial measures, the study adopted the production function approach to construct the TFP index. The study concludes that an increase in the conventional factors of production accounted for the sources of total agriculture growth. Therefore, for the entire period, except for some initial years of the reform period, the TFP of the agriculture sector turned negative. The study suggests that the relative decline of the public investment in agriculture is the prominent reason for the slowdown of agriculture growth. Although the study does not explicitly mention the worsening of the biophysical dimension of sustainability, one can see that a negative trend in TFP has existed in Indian agriculture for an extended period. It also shows “that the quality of the resource base is degraded, and the long-term maintenance and enhancement of the productive resources base of agriculture is not met”.

A study by Shanmugan et al. (2008) attempts to decompose the agriculture “output growth obtained in 15 major states for the period 1994-2003”. “Sources of agriculture output growth are separated from input growth, technical change, and technical efficiency using the random coefficient stochastic frontier production function model”. The study found that “technical efficiency” has declined overtime for all the states, and the average technical efficiency is only 75%. Hence, the study suggests that there is potential to increase the current output by 28% without increasing input through sustained “investment in agricultural research and development, extension services, and infrastructure development”.

On studying the TFP of Indian agriculture, Saikia (2009) reviewed different methodologies of measuring the TFP. Related to the measurement of TFP in agriculture, the study highlights some of the crucial disadvantages of conventional measures of TFP for not including actual decomposition of TFP growth, therefore proposing a factor augmenting approach to TFP growth for decomposition exercise. In the factor augmenting approach, the input should be measured in the efficiency unit and help examine the contribution of individual factors to overall technical change. The study argues that the decomposition of TFP growth into technical change and changes in technical efficiency is helpful in “distinguishing innovations or adaptation of new technologies by best-practice firms from the diffusion of new advanced technology, which leads to improved technical efficiency among the firms”.

Chaudhary (2012), using a non-parametric Sequential Malmquist index, studies state-level trends in TFP in Indian agriculture. This method is called “data envelopment analysis, a non-parametric method of frontier estimation of” production function based on linear programming, which does not require price data set. Data envelopment analysis of TFP in Indian agriculture is decomposed into technical efficiency changes, and technical change alone is the disadvantage of the methodology. Despite that, it is found in the study that productivity improvements are marked in very few states. Technical change in TFP constitutes an important source of growth. Hence, the decline does not occur in total productivity. In other words, the effects of technical progress outweigh the impacts of the decline in technical efficiency changes. Improvement in efficiency is low for most states, and efficiency decline is observed in several states. This finding implies a substantial potential increase in production even with existing technology.

Chand et al. (2012) examined "TFP and its share in output" and "returns to public investment on agricultural research in India from 1975 to 2005". The study adopted the Divisia-Tornquist index approach for computing TFP, and sources of TFP growth were then decomposed for the independent variables such as research stock, extension stock, rural literacy ratio, cropping intensity, N_2O and P_2O_5 ratio, groundwater irrigation index, road density index, electricity consumption per hectare of the cropped area. The share of TFP and growth rate of TFP in the study were found at 2.92 and 0.53, respectively. The “contribution of agricultural research in reducing the real cost of production and attaining food self-sufficiency has also been estimated for the country”. The estimate of TFP has shown “considerable variation across crops in different states at the country level in India from 1975 to 2005”. The study confirmed that “wide variation in TFP growth and that indicate technological gain have not been experienced in a number of crops in many states”. The study found that “from 1990-91 to 2006-07, the TFP growth reduced the real cost of production from 1% to 2.3% annually”. Hence, both consumers and producers have equally benefited. Return on investment in agriculture research has been estimated at 42%, and crop-specific return on investment is also significant.

Birthal et al. (2014) analyse “Changing Sources of Growth in Indian Agriculture: implications for Regional Priorities for Accelerating Agricultural Growth.” The study's particular objectives are to assess changes in agricultural growth sources at the national and sub-national levels over the previous three decades; second, to analyse the economic, institutional, and policy elements driving these changes; third, to investigate the implications of changing agricultural growth sources for small landholders; and finally, to propose methods for greater, “more sustainable, and more inclusive agricultural growth". Patterns and sources of agricultural growth are examined from 1980 to 2010, and the "transformation and sources of growth in Indian agriculture are compared in response to various technological, institutional, and regulatory interventions implemented at different times". The study analysed data on area, yields of roughly 50 different crops, and prices of essential products from 20 main Indian states to analyse the sources of growth. The study grouped entire states into northern, western, eastern, and southern regions for the state-level analysis based on their geographical continuity and proximity. The study used a growth accounting approach similar to Minot's (2006) to break down agricultural growth by sources. Changes in cropped area yields, real prices, and residual factors are dissected from a single crop to determine the causes of gross income growth. According to the study, agriculture grew at a rate of more than 3% per year, with significant year-to-year fluctuation across states. Crop diversification, which gained traction in the 1990s and contributed as much to agricultural expansion as technology, was the main source of growth in the 1980s. In the 1990s, price effects were similarly more potent, but they decreased in the next decade. In the third decade, particularly in the second half, technology resurfaced as a significant source of growth. Agriculture has grown faster in the last three decades as it maintained its momentum in the western and southern regions, which are mostly rain-fed and more diverse than the rest of the country. Agriculture increased at a slower pace in the northern and eastern regions. On the one hand, agriculture in the northern region is influenced by technological factors, whereas in the southern region, growth is propelled by diversification toward high-value crops.

Prashant et al. (2014) attempted to assess agricultural sustainability in changing context for India through a synthesis of trends in arable land, agricultural productivity, water resources, increasing food demand, and growing population and depends on imports, agricultural production, and food consumption per capita. The study found that expansion of the agricultural area in India has shown at the point of saturation and noted a decline in recent years due to an increase in demand for land for non-agriculture purposes. On the one hand, water requirement for irrigation increased for last 50 years whereas, on the other hand, per capita availability of water for the same has shown declined. Food production has also shown at the point of saturation in recent years, and potential production capacity declined. Import requirement decreased due to increases in output.

In terms of the sustainability index, the study found a declining trend in agriculture sustainability based on parameters for the study since the 1990s. The overall conclusion of the study is that primary resources for agriculture are on the decline. Hence, supply will have to be increasingly dependent on external resources like imports in the coming days.

2.5 Reviews with Reference to Kerala Agriculture

Panicker (1980) examines recent trends in rice's area, production, and yield rate between 1960-61 and 1978-79. The study also examines the reason for the decline and its implication on the rice economy of Kerala. This study identified the causes for the decline were a fall in the price of paddy since 1974-75, an increase in cost of cultivation, particularly wage rate of the labors, and improvement in the supply position of rice.

Panicker (1981) studied high-yielding rice varieties in selected areas in Kerala. The main purpose of this study was to investigate socio-economic factors underlying the adoption of high-yielding Varieties of seeds in Kerala. The survey was conducted in the traditional rice bowel selected regions of Palakkad and Kuttanad. A significant finding of the study was that the yield rate of HYVs is far less than the yield rate expected. Low yield to fertiliser, the physiological properties of the new seed varieties are prone to incidents of diseases and pest outbreaks, and high cost of cultivation due to high and rising prices of fertilisers and plant protection materials. The study concluded that the rice economy in the region is in a paradox where modernisation in agriculture coexists without a commensurate improvement in net returns.

Jeemol Unni (1983) investigates changes in cropping patterns in Kerala over a two-decade period. This research is based on evidence from the substitution of coconut for rice between 1960-1961 and 1978-1979. The study also discussed the change in rice area and established that area under rice has shown a tendency to fall in some districts since the early 1960s, more evidently since the 1975s. This study classified the period of area growth under paddy in three distinct phases. The first phase from 1960-61 to 1978-79 showed an increase in the growth in the area under rice. The second phase from 1969-1970 to 1974-1974 showed stagnant growth of area under rice and in the third phase from 1975 to 1978 experienced a perceptible and sharp decline in the growth of area under rice. An important finding of the study was a shift in the cropping pattern in favour of garden land crops, especially coconut, at the expense of wetland crops, particularly paddy.

George et al. (1986) conducted. “A disaggregate analyses of growth performance of rice in Kerala”. The study aimed to analyse the growth pattern of rice in Kerala over and across temporal (1st period 1961-61 to 1974-75-s and 2nd period 1975-76 to 1983-84), particularly (among major rice-growing districts), seasonal basis. The study also looked into the role of HYV technology, irrigation, and relative prices in explaining the changes in the area, production, and yield of rice in Kerala. The growth rate of area, production, and yields were calculated through regression. Additive decomposition analyses were undertaken to understand the impact of the area and yields in changing paddy production. The result showed that the growth rate of area, yield, and production indicate considerable variation across districts, time, and seasons. The results also indicate that the relative price of paddy and coconut influenced the acreage adjustment in paddy, whereas inter-seasonal switching between HYVs and non-HYVs of paddy yields. Furthermore, the proportion of irrigated areas turned out to be insignificant in explaining the paddy yield during the period under study.

Muraleedharan (1987) studied “resource use efficiency in Kole land in the Trichur district of Kerala in new technological change”. The study is based on primary data from the sample of 142 cultivators during the year 1978-79. Cobb Douglas linear production function was fitted for both HYVs and non-HYVs rice cultivators to measure resource use efficiency. Efficiency in resource use was estimated by comparing marginal value products against “their respective factor costs”. Results indicate that “cultivators have not been able to use their resources efficiently”. Hence, there is “considerable scope for augmenting profit from Kole cultivation by optimum use of inputs”.

Thomas et al., (1996) studied the economic causes of the decline of paddy cultivation in Kerala. In addition to economic reasons for the decline in paddy cultivation and its current problems, the study looked into “trends in area, production, yield, and profitability of paddy cultivation in Kerala”. The study also examined different sources of productivity in improving the per hectare yield of paddy for the state. The overall performance of paddy crops is assessed by estimating the growth rate using a semi-log linear curve. An additive decomposition scheme was also introduced to study the relative contribution of components in output changes in different periods (1st period 1960-61 to 1974-75, and the second period 1975-76 to 199 1-92). The study showed that sources of productivity in paddy have not significantly helped to improve its productivity in Kerala. Low profitability of paddy cultivation induced farmers to either put their paddy field as fallow or shift to commercial crops. Based on primary data, the study identified ongoing challenges in paddy cultivation such as price stabilising aspects of PDS, growing pressure on land, land price differential, shortage of labour and capital, absentee land ownership, aversion of younger generation farmers to find farming occupation in agriculture.

Srinivas et al. (2007) studied TFP changes in cassava production in Kerala from 1982-83 to 2001-02 using the Divisia-Tornqvist index. The authors estimated total output, total input, and TFP indices for cassava crops in Kerala. The study analysed the long-term changes in input, output, and cost structure, growth in input, output, and TFP of cassava crop of Kerala. The study found that total output and input indices show significant positive trends, whereas a significant negative trend in the growth of TFP in cassava production was observed in Kerala for the period under study.

“Some of the long-term problems to Paddy Cultivation in Kerala” are addressed in Thomas's (2011) field report. This “report is based on interviews with farmers, government officials, and leaders of mass organizations in Palakkad”. It also intends “to analyze the policy initiatives implemented by the State and Local Governments in recent years that have aided in the revival of rice cultivation in Kerala”. The author of this report argues for the revival of rice cultivation in the state for two reasons. First, as a food - insecure state, Kerala produces only 15% of its food requirements, necessitating imports from nearby states. As a result, the revival of paddy cultivation contributes significantly to achieving self-sufficiency in food grain production. Second, paddy fields are an important part of Kerala's environmental and ecological system, providing natural drainage paths for floodwaters, conserving groundwater, and protecting a diverse range of flora and fauna. The report's key highlights of the “long-term challenges of paddy cultivations” are seasonal labour shortages, low levels of profitability, competition from other crops, and the use of land as a speculative asset.

Aswathy et al. (2013) studied "TFP growth in marine fisheries of Kerala". The objective was "to assess the economic sustainability of the marine fish production system in Kerala by estimating the TFP growth for the period 2000-2010 using the Divisia-Tornqvist indexing method". The assessment shows "negative TFP growth of 3.69%, indicating the economic unsustainability of the production system in the short run". The study concluded that "excess fishing capacity exists above the economically optimum level, resulting in the wastage of money, human resources, and fuel in the fishing industry". Therefore, the study recommends "fishery management measures and optimum use of resources in the sector".

Karunakaran (2014) analysed "TFP growth of the crop sector in Kerala" at the state and district levels. The study aimed "to examine the performance of production and sustainability of a growth process of the crop sector in Kerala for the period 1987-2010". The study measured the TFP index using the Divisia-Tornqvist index. The study also estimated the share of "TFP in output growth of the crop sector in" Kerala. The study's finding revealed "stagnation in the crop sector since a negative and very low annual TFP growth rate" was observed in Kerala. District level analyses also showed similar trends in TFP growth. Furthermore, the study revealed that "for all districts except Kollam, Idukki, Wayanad, and Palakkad, the state as a whole, the share of TFP in output growth was negative" for the period under study. Therefore, the study concluded "a clear sign of unsustainability of the crop sector".

2.6 Reviews of Impact of Farmers Adaptation Practices to Climate Change on Technical Efficiency

Akinnagbe et al. (2014) review "agricultural adaptation strategies employed by farmers in various countries in Africa in cushioning the effects of climate change". The study classified entire "adaptation strategies" under three categories: "crop, livestock, and others". The study found "common agricultural adaptation strategies used by farmers were using drought-resistant varieties of crops, crop diversification, changes in cropping pattern and calendar of planting, conserving soil moisture through appropriate tillage methods, improving irrigation efficiency, and afforestation and agro-forestry". The study concludes "that improving and strengthening human capital through education, outreach" programs, “extension services at all levels will improve capacity to adapt to climate change impact”.

Auci et al. (2014) studied "Climate change effects and Agriculture in Italy: a stochastic frontier analysis at a regional level". Their study aimed “to analyse the economic impact of climate change on the agricultural sector in Italy at a regional scale”. Using the stochastic frontier approach, the study investigated the Italian region's efficiency from 2000 to 2010. The study found that rainfall and minimum temperature are the two important meteorological factors influencing inefficiency. More specifically, the study discovered that rainfall variables positively impact efficiency, whereas the “minimum temperature variable reduces the efficiency of agricultural production”. This study treated the direct effects of climatic variables in determining the efficiency of agricultural production. However, one of the critical effects of climate change is the adaptation practice in agriculture. For example, in addition to climatic factors, socio-economic variables considering climate change at different levels may also influence agricultural production's technical efficiency.

Makki et al. (2012) studied “the impact of climate change on the productivity and efficiency of paddy farms in south Kalimantan province, Indonesia”. The objective study was to understand changes in the production and productivity of rice in the context of climate change. The study used the stochastic frontier analyses and found that management at the farm level variables in determining the success of rice-based farming systems in the tidal lands in the context of climate change. Therefore, the study recommends encouraging adaptation by training and education of farmers.

Otitoju et al. (2014) studied "climate change adaptation strategies and farm-level efficiency in food crop production in southwestern Nigeria". The study brought out explicitly the adaptation strategies and technical efficiency in the analysis. The main objective of their study was to understand the effects of climate change adaptation on farm-level technical efficiency. Based on the primary samples of 360 farm households, the study identified “multiple cropping, land fragmentation, multiple planting dates, mulching, and cover cropping” as the “major climate change adaptation strategies”. The study also found that adaptation strategies such as land fragmentation and multiple planting date reduce technical efficiency, whereas social capital and years of climate change awareness significantly increase farms' technical efficiency. This study concludes by suggesting cooperative farming as an adaptation strategy in the context of climate change.

Kumar S, et al. (2019) studied "Input-use efficiency of adaptors of climate-resilient technology in paddy and wheat crops in Punjab Agriculture." The purpose of the study was to evaluate the effect of climate-resilient technology on the production efficiency of rice and wheat crops in Punjab agriculture. Using Data Envelop Analyses, the study compared the technical efficiency of adopters and non-adaptors of climate-resilient technologies “based on both primary and secondary data”. The study found that the adaptors of both direct-seeded rice in the case of paddy and zero-till in the case of wheat were most efficient. The study also found that adaptors of climate-resilient technology such as laser leveller and improved wheat varieties are more efficient. In sum, the study found that “the technical efficiency in crop production has been found higher for technology adapters than non-adapters”. Therefore, the study suggests an increase in the farmers' adaptive capacity, which can be through synergy between agricultural research, agricultural extension, insurance, and institutional support.

Mugera et al. (2012) conducted their first empirical study on “The impact of climate variability on production efficiency and income of Kansas farms”. The study's general goal was to look into the “impact of climate variability on” farm “production efficiency in Kansas”, USA. “Temperature and precipitation” effects “are modelled” using various “stochastic production frontier” specifications. The study's specific goal was to use a fixed-effects panel regression model to investigate the “impact of climatic variability on total farm income, crop income, and livestock income”. “Climate variability”, according to the study, “has a significant impact on mean output elasticities for input, return to scale, and technical efficiencies. Purchased inputs are more vulnerable to climate change than capital and labour”.

Deraniyagala (2001), in a study on "Adaptive technology strategies and technical efficiencies: evidence from Sri Lankan agricultural machinery industry," distinguishes between two types of technological strategies developed elsewhere. They are the non-adapted (direct application of technology without modification) and adapted technological strategies (applies technology with modification to suit context). The study found that the technical efficiency of former adaptive strategies has a significant positive effect on the efficiency of the agricultural machinery industry, using a stochastic frontier production function. However, this study has not examined the context of climate change where farmers' adaptation to different technologies is likely to influence the technical efficiency of their farms.

Roco et al. (2017) studied “The impact of climate change adaptation on agriculture productivity in central Chile”. This study's objective was “to analyse the impact of climate change adaptation on the efficiency of annual crops in central Chile” using a stochastic frontier approach. Based on primary samples of 256 farms located “in different agro-climatic conditions”, the study measured “climate change adaptation” with “a set of 14 practices”, which were further clubbed under “three different specifications”, such as “binary variable, count, and index: representing decision, intensity, and quality of adaptation respectively”. These different adaptation “variables were used in three different stochastic production frontier models”. The study found that farmers' adaptation practices significantly improve productivity. The study also reveals that farmers' “adaptation to climate change in the form of” improved irrigation facilities significantly increased the technical efficiency of the farms. Thus, the empirical results of this study show the importance of “climate change adaptation on farmers' efficiency and enrich the discussion regarding the need to implement adaptation measures”.

Shimada et al. (2019) studied “The effects of climate-smart agriculture and climate change adaptation on the technical efficiency of rice farming in the Mekong Delta of Vietnam”. The study's objective was to “assess the effects of climate-smart agriculture participation and climate change adaptation response on the technical efficiency of rice production”. Based on primary “data collected from 352 rice farm households of Mekong Delta of Vietnam, the study found that 71% of farmers adapted” and 29% did not adapt to climate change. Using the propensity score matching approach, the results of this study also show “that adaptation to climate change in the form of climate-smart agriculture participation increased the technical efficiency of the rice farmers by 13-14 % more relative to those of the non-adapters".

Vijayasarathy et al. (2015) studied "climate adaptation in agriculture through technological adoption and determinants and impacts of production efficiency". The study's objective was to understand the determinants of "climate adaptation technology and its impact on the technical efficiency of production of major crop production using a multi-nominal logit model", The study found that "education level, sex, household size, farm size, extension contact, temperature and rainfall are the major factors that influence the adoption of technologies to reduce the impact of climate change variability". Using the "stochastic frontier production function, the study discovered that adopting technology to adapt to climate variability significantly increases crop production technical efficiency". The study concludes by identifying lack of finance, "lack of knowledge about the technology, and high cost of adaptation are the major constraints for the farmers' adaptation to climate change".

Owoeye (2020) conducted a study "comparing climate adaptation strategies on technical efficiencies of Cassava production in southwest Nigeria". The study aimed to describe relevant socio-economic characteristics and "assess the influence of used adaptation strategies on the technical efficiency of Cassava production in two agro-ecological regions". Based on primary data samples of 300 cassava producers and stochastic frontier production analyses, the result of the study revealed the existence of technical efficiency in cassava production on account of farmers' adoption of used adaptation strategies in their farm production. The study concludes by recommending that farmers undertake multiple "adaptation strategies to climate change, such as crop diversification, multiple planting dates, land fragmentation, improved verities, and multiple planting dates".

Mukherjee et al. (2012) focus "on the potential impact of heat stress on milk production efficiency for a sample of dairy farms from the south-eastern US". The "econometric models developed in the study are" helpful "to quantify the gross benefits expected from adaptation to climatic conditions represented by the Temperature Humidity Index (THI) and alternatively by the Equivalent Temperature Index (ETI)". "Stochastic production frontier analysis is used to measure technical efficiency for an unbalanced panel of 103 dairy farms in Florida and Georgia. Five alternative model specifications are evaluated". "The results reveal that both THI and ETI have a significant nonlinear negative effect on milk production". When incorporated in the frontier specification, the "climatic indexes" absorb some of "the output" shortfalls "that otherwise would be attributable to inefficiency". "The results also indicate that using fans combined with sprinklers is an effective adaptation to offset output losses stemming from heat stress conditions".

Demir et al. (2002) argued "that agro-climatic and other environment variables are customarily omitted in the model specifications and should not be treated as pure random terms". Therefore, the study demonstrates the importance of agro-climatic variables in the technical efficiency analyses of agricultural production and recognises "that the exclusion of environmental factors may lead to biased" technical efficiency "scores". A "trans-log stochastic frontier production function with agro-climatic variables such as rainfall and land quality is estimated". It is shown that "the agro-climatic variables are statistically significant and that their omission substantially affects mean output elasticities" and "relative technical efficiencies".

Sherlund et al. (2002), in a study of "smallholder technical efficiency controlling for environmental production conditions," reconsider "inference with respect to technical inefficiency when one controls carefully for environmental production conditions". More specifically, the study shows that "the neglect of inter-farm heterogeneity in environmental conditions such as pest and weed infestation, plant disease, and rainfall leads to obvious omitted variables bias in the estimated parameters of the production frontier". It also "leads to significantly inflated estimates of plot-specific technical inefficiency and bias in estimates of the correlates of technical inefficiency".

Salat et al. (2018) examine "the resource use efficiency of maize production among smallholder farmers in Nyando, Kenya". The purpose of the study was "to assess the degree of technical efficiency of smallholder farmers" and "identify the impact of so-called climate-smart practices on technical efficiency". The study used "stochastic frontier analysis to simultaneously estimate a stochastic production frontier and a technical inefficiency effect model". Based on primary samples of 170 farm households, the study revealed that climate-smart adaptation practices of "soil conservation practices (such as residue management, legume intercropping, and improved varieties) significantly increase farmers' technical efficiency”. Therefore, the study suggests that soil conservation practices should be an essential "climate-smart" adaptation practice because such practices can increase “soil carbon, production, climate resilience, and technical efficiency”.

Khanal et al. (2018) “examine the impact of climate change adaptation practices on technical efficiencies among smallholder farmers in Nepal”. The study included “an adaptation index” in a stochastic frontier framework. The study is based on stakeholder workshop and household survey data from three agro-ecological zones of three districts shows that 91% of farmers adapted to “climate change”. The “empirical results reveal that adaptation is an important factor explaining efficiency differentials among farming households”. Therefore, this study suggests that “policymakers make small-scale adjustments in response to climate change impacts effectively improve efficiency in agricultural production”. This indicates a need for farmers' involvement in climate change adaptation planning.

Cholo et al. (2020) studied "land fragmentation, technical efficiency, and adaptation to climate change by farmers in the Gamo highlands of Ethiopia". This study attempts to point out how to land fragmentation and land management jointly as an adaptation strategy influence technical efficiency in the case of bare production. The study adopted “two stochastic frontier panel models on plot-level cross-sectional data and found that fragmentation influences the effect of land management practices on efficiency”.

Adzawla et al. (2021), on "Effects of climate adaptation on technical efficiency of maise production in Northern Ghana", discusses the essential role of climate changes “adaptation strategies for sustainable food” and output “production in” agriculture. The objective of this study is “to analyse the effects of climate adaptation strategies such as conservative agriculture (CA), integrated soil fertility management (ISFM), integrated pest management (IPM), and changing planting dates on the technical efficiency of maize production”. The major variables of “climate adaptation strategies adopted by the farmers include row planting, changing planting date, mixed farming, refilling, and intercropping” to increase farm production. Based on 619 samples of primary data, stochastic frontier model estimation “shows that while climate adaptation significantly leads to higher maize outputs, only crop rotation and row planting significantly improve the technical efficiency of maize farmers”. Other factors that significantly influence maize output are “farm size, labour, seed, and chemicals”. The study concludes that “climate adaptation, particularly crop rotation and row planting, remains essential adaptation strategy for sustainable food production in the region”.

Adzawla et al. (2021) studied the “effects of climate adaptation on technical efficiency of maise production in northern Ghana”. “Cobb-Douglas stochastic frontier model” is fitted to the data. The study results show that “the major climate adaptation strategies adopted” by the farmers include “row planting, changing planting dates, mixed farming, refilling, and intercropping”. The frontier result shows that while “climate adaptation significantly leads to higher maize outputs”, only “crop rotation” and “row planting” significantly improve the technical efficiency of maize farmers. Other factors that significantly influence maize output are farm “size, labour, seed, and chemicals”. The study concludes that “climate adaptation, particularly crop rotation and row planting”, remains an essential adaptation strategy for sustainable food production in the region.

Using a different methodology, Suresh et al. (2006) conducted “economic analyses of paddy cultivation resource-use efficiency in the Peechi command area of Trissur district” of Kerala. Along with resource productivity, the study examined “allocative and technical efficiency”. Based on stratified sampling, “primary data were collected from” 71 rice farmers. The productivity of the resources used in paddy cultivation was estimated “using the Cobb Douglas production function”. Allocative efficiencies were determined by calculating the “Marginal Value Product” (MVP) ratio to the “Marginal Factor Cost” (MFC) Fixed parameter frontier approach, and Timmer measure is adopted to estimate technical efficiencies. The study found that the cost of paddy cultivation in the command area was Rs 21603/ha. “Elasticity coefficients for farmyard manure, fertiliser, and human labour were significant and positive”. “The average technical efficiency of paddy” production in the study area stood at 66.8%. “Education and supplementary irrigation facilities” have been identified as the important determinant of enhancing technical efficiencies.

2.7 Reviews on the Challenges of Paddy Cultivation in Kerala, Wayanad and Palakkad.

Much research has been conducted to investigate the problems of paddy cultivation in Kerala. In "the Shrinking rice paddies of Kerala", Nikhil et al. (2009) argued that for lack of justifiable economic returns, Kerala paddy farmers have practically abandoned rice cultivation in favour of cash crops or left their land fallow for years. The study identified changes in the State's socio-cultural settings, urbanisation, infrastructural development, economic empowerment owing to overseas remittances, insufficient wetland conservation legislation, and a surge in real estate enterprises as the factors that endanger the paddy cultivation in Kerala.

Thomas (1996) identified several concerns relevant to the problems of paddy cultivation in Kerala in research on economic factors for the decline of paddy cultivation of Kerala. It includes a decline in full-time labours and a growing aversion among the younger generation to paddy farming, farmers' unwillingness to farm second crops, an exploitative land lease system, lower wages and labour shortages, farmers' poor economic status, high input costs, indebtedness to informal credit sources, insufficient marketing and infrastructure facilities, and improper extension services.

In research on the economic causes of decreased rice production in Kerala, Varkey (2004) concluded that rice cultivation in Kerala has practically reached the final phase of total disappearance. Farmers' realisation that rice is not an economically sustainable crop, increased costs, poor yield, lower profit, and higher-paying opportunities are the significant economic reasons behind Kerala's declining rice production. Poor profit from rice and the ease of moving rice fields to more profitable crops have undoubtedly influenced rice farmers to favour other crops.

In a case study of "the relevance of wetland conservation in Kerala", Sheeba et al. (2015) identify causes and effects of paddy land conversion in Kerala. Non-availability of labour during peak season, declining profitability of the crops, slow pace of mechanisation, lack of credit and marketing facilities, uneconomic size of holdings, lack of irrigation facilities, are the some of the important among them.

In their "scenario analysis of rice farming in Kerala," Hari et al. (2016) identify technological, economic, social, ecological, and political factors for shifting rice cultivation in the State.

Kumar et al. (2021), substantiate structural transition in agriculture from food crops to cash crop farming in Kerala in their "leading concerns and challenges in the agriculture sector of Kerala".

Abhilash (2016) documents in his "rice farming in major wetlands of Kerala" that the whole coastal area of the State is “monocropped with rice as the only crop during the monsoon season”. “Due to a lack of good quality irrigation facilities and significant soil salinity, the area remains fallow for the rest of the year”. The State's principal rice farming areas include “the lowland flooded areas such as Kuttanad, Pokkali, Kole, and Kaipad and the midland and high range areas”. The lowland ecosystem contributes 37 per cent of rice output in the State. Pollution, eutrophication, encroachment, reclamation, mining, biodiversity loss, and real estate threat were highlighted as challenges with wet-land paddy production.

Karunakaran (2014) identified price and non-price factors for crop diversification in his study "Paddy cultivation in Kerela- trends, determinants, and effects on food security." These factors included “agro-climatic conditions, labour availability, irrigation facilities, cost of cultivation, price levels, profitability, and mechanization”. The study warns that the State's food security is in peril since Kerala has a rice shortage relative to demand, which has increased from 40.12 per cent in 1960-61 to 83.45 per cent in 2009-10.

In their field note on "paddy farming in times of climate change", Sreeja et al. (2021) cited several reasons for the conversion of paddy fields to non-agricultural resources extractions, it includes "real estate speculation, infrastructure development project, cultivation of non-rice seasonal crops such as banana, tapioca, or perennial tree crops of coconut, areca nut, rubber, land fragmentation, migration to the middle east, remittance economy, labour shortage, high production cost, low product price."

Thomas (2002) looked into the issues and prospects of paddy cultivation in a village-level study based on the Kuttanad region." Significant problems were identified include labour shortages, declining profitability, crop failure, insufficient research and extension services, and trade union dominance.

Promod (2002) studied the modernisation of paddy cultivation based on mechanisation in Palakkad. The study found that the introduction of machinery in the study area does not reduce dependence on human labour costs in paddy cultivation in Palakkad; therefore, the study concluded further scope for mechanisation.

Thomas (2011), in his micro-level study based on discussion with farmers and officials, reported a range of issues such as seasonal shortages in labour supply, low levels of profitability, competition from other crops, land as speculative assets that affect paddy cultivation in Palakkad.

According to the GoK (2012) research, "An integrated development of paddy agriculture of Malampuzha of Palakkad," based on SWOT analysis, climate change is a severe threat to paddy cultivation. According to the study, paddy production is rapidly disappearing due to various factors, including high wage rates, high cultivation costs, high fertiliser and pesticide prices, labour scarcity, and insufficient irrigation facilities.

Shanmugasundaram et al. (2021) evaluated "resource usage efficiency in SRI rice cultivation in Palakkad." According to the study, the SRI technique of rice production offers an alternative to dealing with existing challenges in paddy farming, such as groundwater scarcity, protracted dry spells, and dwindling rice cultivated areas. Although the SRI method of cultivation can address resource use inefficiency in paddy cultivation with higher grain yields and net returns, the SRI method involves high cultivation costs due to intercultural variation in harvesting and planting operations, hence constraining from a profitability point of view.

The district's human development report of Wayanad (2009) pointed out that the rapid collapse of agriculture, particularly paddy production, is a source of concern with long-term implications for food security and the region's ecological and environmental balance.

Santhoshkumar (2010) published a study as a part of the Satoyama Initiative, UN University Institute of Advanced Studies titled "The Home Gardens of Wayanad" highlights homestead farming in Wayanad also involve paddy based cropping system at the subsistence level, which consists of paddy, vegetables and banana. This study mentioned policy changes, institutional problems, geographical idiosyncrasies, climate change effects, low agricultural investment, and infrastructural facilities as reasons for agriculture failure in Wayanad.

Vishnudas (2003) proposed a "System of Rice Intensification" for rejuvenating paddy cultivation for the Wayanad district. Although the study found cultivation costs to be 5 to 13 per cent higher than conventional methods, given the endangered context of paddy cultivation in Wayanad, being a technological intervention and innovation and support services to bring back paddy fields in Wayanad, this method has the potential to increase productivity, reduce labour costs, and develop eco-friendly pest and disease management; thus SRI can be very well propagated in the district.

Krishnankutty et al. (2021), in their socioeconomic analysis of the “sustainability of traditional rice cultivation in Kerala, found that traditional farmers are aging, have lower education, and use limited marketing channels”. “Traditional rice varieties and cultivation are declining in most rice-growing areas”, owing primarily to low productivity. Because of its higher nutritional, environmental, and superior quality, traditional varieties hold the key to the sustainability of rice cultivation.

Gopi et al. (2008) explore the “speciality rice biodiversity of Kerala: the need to incentivise conservation in the era of changing climate”. According to the study, “indigenous rice varieties in Kerala have lost out to modern varieties”. Traditional rice varieties, the study argues, can “adapt to climate change and are best suited for climate-resilient agriculture”, giving a “rich reservoir of genetic material for anticipatory research to combat the impact of climate change on agriculture and food security”.

Rasheed et al. (2021) investigated "who cultivates traditional paddy varieties and why?" Findings from the Wayanad district of Kerala conclude that the socioeconomic and cultural significance of traditional paddy varieties and their genetic diversity make paddy farmers invaluable for future crop improvement strategies, particularly in the context of climate change, which necessitates their conservation.

Rasheed et al. (2021) conclude in a study of "ecosystem valuation and eco compensation for conservation of traditional paddy ecosystem and varieties in Kerala, India" based on primary data from Wayanad traditional paddy growers that the Wayanad paddy ecosystem generates US dollar 8,391 ha-1 worth of ecosystem services annually, of which 77 per cent is non-marketed. According to the study, farmers were willing to take a mean compensation of US dollar 106 ha-1 as an incentive to produce traditional paddy varieties, which was lower than the government incentives under the Wayanad package programme. As a result, the study recommends that payments for incentivising paddy production consider the value of ecosystem services.

2.8 Issues and Research Gaps

There exist several studies on the topic of agricultural sustainability. Since it is essentially multifunctional, it is difficult to find unifying themes on agricultural sustainability. Components characteristics of the different contexts of agriculture vary widely, and it is found to be the main reason behind disagreement among scholars about the various dimension of agricultural sustainability. Diversity of the agriculture context demands a context-specific approach in approaching agricultural sustainability. In that respect, “agricultural sustainability” will remain an ever-widening field of research in the future. Few studies have identified several climate and weather risk adaptation strategies currently being used and their link to sustainable agriculture practices.

How far agriculture will be sustainable in the coming days depends on how well the farming system has adapted to changing climatic risks and uncertainties. The literature has found that maintaining TFP for a long period is the predominant criterion for sustainability studies. However, against the context of the likely future impacts of climatic risks, the agriculture adaptation practices and methods may be the determinants of agriculture sustainability because farmers' adaptation practices and coping strategies influence technical efficiency and hence sustainability. For instance, efficient adaptation practices from available practices by the current farming system may represent agriculture sustainability. Therefore, it can be hypothesised that the extent to which adaptation capacity or resilient character of agriculture determines agriculture sustainability in the context of likely future impacts of climate change. That aspect has not been addressed so far in the studies of agriculture sustainability.

In the context of adaptation and vulnerability to climate change, Adger et al. (2004) propose the first steps towards assessing indicator system-based studies. That can be held in the case of agriculture sustainability. Therefore, to assess agriculture sustainability quantitatively, we must develop indicators to represent these variables. However, for this to be possible, we must first develop a coherent conceptual framework of agriculture sustainability in the context of climate change. For that, one must see before the factors that constitute agriculture sustainability. Once we have developed such a framework and identified the elements of agriculture sustainability, we must choose appropriate proxies from which to construct our indicators.

Two issues are emerging in the above literature. Impacts of climatic risks are one issue, and agriculture sustainability is the other. Literature that deals with agriculture sustainability have rarely unravelled climatic risks and uncertainties dynamics, although many pieces of literature come across the influence of environmental components. Therefore, one has to club both issues together in further research. In short, for an agriculture production system to be sustainable, setting adaptation practices and coping strategies may be directed as per the principles of sustainable agriculture. Although few emerging kinds of literature try to assess the relationship between adaptation practices to climate change by farmers and efficiency of agriculture, combining both adaptation and coping strategies and their influence on technical efficiency is not yet addressed in studies.

CHAPTER 3

PERFORMANCE OF PADDY CULTIVATION IN KERALA

3.1Introduction

Economic Review of the Kerala state for the year 2014 reported that, from 1980-81 to 2013-14 periods, there was a decline in the contribution of agriculture to the Gross State Domestic Product from 36.8% to 8.95% (Economic Review 2014). More recently, from 2013-14 to 2019-20, agriculture contribution dropped by 4%. Vaidyanathan (2006) argues that agrarian crises culminated in country-wide farmers' suicide due to the adverse impacts of trade liberalisation and the unbearable debt burden of farmers. He also pointed out that recent episode of farmers' suicide indicates deep-rooted symptoms of agrarian distress, and suicides are concentrated mainly in the low rainfall, poorly irrigated regions. Namboodiri (2005) identified declining profitability of the crops, an enormous increase in the land price, and a high rate of conversion of agricultural land to other purposes are the other factors for the current issues in Kerala agriculture. However, O'Brien (2000) and Jørgensrud (2014) argued that trade liberalisation and climatic vagaries subjected farmers to multiple exposures to vulnerabilities, worsening the agrarian crises. For instance, Gagdekar (2013) discussed that distress caused by drought due to poor monsoon performances worsened the living condition of the farmers. Since 2012, extreme climatic conditions such as drought have resulted in crop failure and debt traps, causing a large number of farmer's suicide in states such as Andhra Pradesh, Marathwada regions of Maharashtra, and in different parts of Kerala.

SAPCC (2008) states that “Kerala is specifically vulnerable to climate change owing to its location along the sea coast and the steep gradient along the western slopes of the Western Ghats”. The reports also pointed out that extreme precipitation causes heavy soil erosion increased water use in the upland leading to salinisation in the coastal zones. Hence, climate changes pose severe threats to the agriculture economy of Kerala. Economic review (2010) reported from the analyses of rainfall data span from 1950-2003 that there is an increasing tendency in winter and autumn extreme rainfalls and decreasing trends in spring rainfalls with increasing frequency of dry days.
State Action Plan 2008 on Climate Change projects that Kerala state will severely be threatened by the likely impacts of future climate change. Atmospheric temperature over Kerala will increase by 2 degrees Celsius by the middle of the 21st century. It also projects that the number of rainy

days will decline and increase the minimum temperature across the Western Ghats region. Sea level rise will submerge the 169sq km of coastal zones. SAPCC projects that paddy production will drop by 6% to each degree rise in the temperature. Changes in the temperature and rainfall pattern also influence the area, production, and productivity of thermo-sensitive crops predominantly grown in high-altitude regions (SAPCC 2008). Along with other factors, climate change issues perhaps contribute more to the dismal performance of the agriculture sector of Kerala.

The present chapter consists of three sections. The first section examines production performance, especially Kerala's land-use and cropping patterns. The comparative analysis is carried out for Wayanad and Palakkad districts. The analysis of the area, production, and productivity of paddy cultivation in Kerala will be discussed in the second section. A comparative analysis of paddy cultivation for the Wayanad and Palakkad district is carried out in this section. The last section dealt with the economics of paddy cultivations from the perspective of cost-efficiency.

3.2 Agriculture Growth in Kerala.

According to Kerala's economic review for the year 2020, the agriculture sector is facing severe growth crises. As per the Directorate of Economics and Statistics data, Kerala's agriculture and

Table: 3.1 Share of Agriculture and Allied Sector in GSDP of Kerala

Year	Share of Agriculture and Allied sectors in total GSDP(Kerala)	Year	Share of Agriculture and Allied sectors in total GSDP(Kerala)	Year	Share of Agriculture and Allied sectors in total GSDP(Kerala)
1960-61	56	**2002-03**	18.89	**2012-13**	13.76
1975-76	42.7	**2003-04**	16.98	**2013-14**	12.90
1994-95	26.62	**2004-05**	17.8	**2014-15**	11.92
1995-96	25.78	**2005-06**	16.67	**2015-16**	10.74
1996-97	25.39	**2006-07**	14.48	**2016-17**	9.96
1997-98	23.67	**2007-08**	13.20	**2017-18**	9.6
1998-99	22.7	**2008-09**	12.70	**2018-19**	9.03
1999-00	22.03	**2009-10**	11.50	**2019-20**	8.38(P)
2000-01	21.38	**2010-11**	10.1	**2020-21**	9.44(Q)
2001-02	19.63	**2011-12**	14.38	**2021-22**	NA

Source: Kerala Economic Reviews. Up to 2010-11, the base year for GSDP is 2004-05. Since 2011-12, the GSDP expressed in 2011-12 base year. Note: (P) Provisional, (Q) Quick allied sectors recorded a growth rate of 1.43% in 2012-13. However, the sector experienced a negative growth rate for the subsequent three years. For instance, in 2013-14, the agriculture sector growth rate declined to low - 6.31%, and in 2014-15 and 2016-16, Kerala agriculture growth stood at -1.09% and - 2.9%, respectively (Economic review 2018). In 1960-61, Kerala's share of agriculture products was nearly 56 % of Net State Domestic Product (NSDP). However, the Agriculture and Allied Sectors share in the state GSDP also declined from 14.38% in 2011-12 to 10.74 % in 2015-16, and again decreased to 8.03 % in 2019-20.

3.3 Land-use Pattern in Kerala.

Land use and cover changes play a significant role in climate change at different scales, such as regional, local, and global (Pawan 2021). At the global level, land use and cover changes contribute to the emission of greenhouse gases into the atmosphere, thus driving towards global warming. Land-use pattern changes also affect carbon balance through terrestrial soil and vegetation (Shukla, 2019).

The land-use pattern in Kerala has undergone tremendous changes since 1975. The existence of the required forest area has a greater potential to influence the micro-climatic condition of the locality. However, the forests resources in the state have declined at an unprecedented rate (SAPCC, 2014). Kerala had 44 % forest area in 1905. At present, out of 3885497 Ha of the total geographical area of Kerala, the total forest area constituted only 28 % in 2010. Though the official figure shows a constant state of land under forest area, other studies based on long-term data spanning more than a hundred years and satellite images establish a drastic reduction in the forest area. Forest encroachment coupled with agriculture expansion with the given high population density makes constraints to the further expansion of forest area in the state. Kerala now has a very dismal fraction of land under permanent pasture over a long period, and the share of which has been very negligible since 1990.Data related to land use statistics delineate that the net sown area declined to 52.20% in 2019 from 57.56% in 1995. The expansion of the net sown area is stagnant and declining for the period under study. Kerala is dominated by rain-fed agriculture, and only 18% of the net sown area is being irrigated. Climate change-induced water stress may cause constraints for the expansion of the net cropped area. The land-use pattern in Kerala also reveals that agricultural land cropped for more than once decreased from 20.61% in 2000-2005 to 11.9 %

in 2015-2019. It indicates that decline in the gross cropped area where the expansion of the same is primarily conditioned by adequate water availability for the second season of the same agriculture year. State action plan on climate change reports predicts that the number of rainy days will decline along with the decline of post-monsoon rain and an increase in the minimum temperature across the Western Ghats region. Therefore, climate variability in the form of decline in rainfall during post-monsoon may impact agriculture land-use patterns. The land-use pattern in Kerala reveals that land put to non-agricultural use has been increasing for the period under study. It can be clear from table 3.2 that during 1975-80, the proportion of land put to non-agriculture use was 6.68% of the total geographical area. It increased further over the years to 9.4 % during 2015-19. The crop failure stems from climate change factors that decreased agricultural land's profitability, and hence systems forced to convert it into other riskless income-generating assets such as for construction and real estate purposes can be the one reason. Long-term increase in the land under non-agricultural purposes can be conceived as a strategic adaptation mechanism,[15] where risk-bearing farmers might be adjusting to climate changes by shrinking agricultural land and converting it for other non-agriculture use.

Moreover, continuous decline in the land under food crops, particularly paddy and tapioca, which require water throughout the growing season. Sudden shifts in the cropping pattern since the 1980s in favour of thermal and excess moister resistant perennial crops that are dominantly driven by commercialisation in agriculture in Kerala may be understood against the background of strategic adaptation to agriculture. Long-term adaptation results in gradual changes in the land-use pattern. For instance, there was a series of drought episodes in Kerala since the 1980s and continued until 1987(Nathan 2000), forcing many farmers to render significant losses; in turn, there was a drastic reduction of the land under agricultural food crops, and converting land for non-agricultural purposes.

[15] Smit et al, (2002) discusses about "Strategic adaptation" which includes among other, changes in the land use, enterprise mix, crop type or use of insurance while analyzing typology of adaptation options in agriculture to climate change.

Table: 3.2 Land-use Pattern in Kerala

Classification of Land	1975-80	1980-85	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-19
Total Geographical Area	100	100	100	100	100	100	100	100	100
Forest	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83
Land put to Non-Agricultural Uses	6.68	7.05	7.21	7.89	8.44	10.26	10.84	10.35	9.4
Net Area Sown	56.57	56.19	57.01	57.76	58.18	56.26	53.99	52.77	52.20
Area Sown more than once	18.58	17.88	18.79	20.37	18.91	20.61	18.21	14.87	11.9
Gross Cropped Area	74.13	74.06	75.75	78.13	63.57	76.87	72.20	67.63	66.6
Barren and uncultivated land	2.06	2.21	1.87	1.38	0.79	0.75	0.63	0.41	0.30
Permanent Pastures & Grazing land	0.29	0.13	1.08	0.04	0.02	0.01	0.01	0.01	0
Land under miscellaneous tree crops	1.81	1.44	1.07	0.88	0.88	0.32	0.17	0.08	.01
Cultivable waste	3.09	3.33	3.01	2.32	1.68	1.67	2.26	2.48	2.5
Fallow other than current fallow	0.63	0.70	0.72	0.71	0.77	0.97	1.17	1.43	1.3
Current fallow	1.02	1.12	1.19	1.17	1.57	1.88	1.97	1.88	1.6
Cropping intensity	131.0	131.8	132.9	135.3	109.3	136.6	133.7	128.2	127.6

Sources: 1. Economic reviews from 1975 to 2020, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics. Directorate of Economics and Statistics, Government of Kerala. Note: All figures are in thousand hectares expressed in per cent to the total geographical area of Kerala state.

3.3.1 Land-use Pattern in Palakkad.

It can be inferred from Table 3.3 that the net sown area and gross cropped area to the total geographical area of the Palakkad district declined for the period under study, whereas land put to non-agriculture purposes is on the increase. Changes in the net sown area roughly stood at a stagnant state; however, a decrease in the area cropped for more than once has led to a decline in the total cropped area. On the other side, land put to non-agriculture use increased to 10.8 % in 2015-19 from 6.93% in 1985-90. The gross cropped area and the net sown area have decreased from 73.52% and 49.34% in 1985-90 to 61.40 and 49.33% in 2010-15. These factors have contributed to a decline in the cropping intensity in Palakkad district from 149 % in 1985-90 to 140 % in 2015-19. Similar to the changes in the agricultural land-use pattern in Kerala, changes in the agricultural land-use pattern in the Palakkad district could also be perceived against the context of climate change. Being rain-fed and irrigated nature of the Palakkad agriculture economy, the expansion of area under cultivation of crops more than once a year is greatly conditioned by the availability of adequate irrigation water and sufficient rainfall. In the context of greater climatic variability and changes, strategic adaptation practices employed by the farming sector must have been the possible reason for the decline in the agricultural land-use pattern on the one side and an increase in the non-agriculture land-use pattern on the other. Even though barren and uncultivated land, permanent pastures, and grazing land, land under miscellaneous tree crops declined between 1985 and 2019 periods, cultivable waste and total fallow land outweighed in its land-use pattern in Palakkad and hence could not contribute to the use of the land available for the net sown area. Palakkad district is dominated by the non-food cropping pattern which is perennial in nature, causing constraints in the expansion of area sown more than once a year. As a result, strategic adaptation to cropping patterns favoring non-food crops resulted in stagnant changes in the net sown area.

Table: 3.3 Land-use Pattern in Palakkad

Land Use Classifications	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-19
Land put to non-agricultural uses	6.93	7.95	10.02	11.25	8.26	9.96	10.8
Net area sown	49.34	46.70	47.40	45.77	44.44	49.33	44.5
Area sown more than once	23.77	31.19	24.43	26.17	26.80	22.86	17.7
Total Cropped area	73.52	77.90	71.82	72.12	71.24	61.40	62.2
Barren and uncultivated land	2.60	1.96	1.03	0.79	2.46	0.46	0.4
Permanent Pastures and Grazing land	0.04	0.02	0.01	0.00	0.00	0.00	0.0
Land under miscellaneous tree crops	1.86	1.65	0.75	0.32	0.42	0.17	0.1
Cultivable waste	5.40	5.14	3.72	4.41	5.84	5.34	4.7
Fallow other than current fallow	1.19	1.43	1.85	2.16	2.28	3.25	3.1
Current fallow	1.74	2.77	2.89	2.83	3.05	2.95	2.4
Cropping intensity	149.0	166.8	151.5	157.6	160.3	124.5	140.22

Sources: Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures are in thousand hectares expressed as a proportion of the total geographical area of Palakkad district.

3.3.2 Land use Pattern in Wayanad

Similar to the land-use pattern observed in the Kerala and Palakkad district depicted in the previous section, Wayanad district has experienced different land-use pattern changes for the period under consideration. The Agricultural land-use pattern in Wayanad increased until 2000-05 and then started declining its share in the total geographical area. It is clear from Table 3.4 that the expansion of the net sown area in the district stood stagnant at 45% of the total geographical area of the Wayanad during the period under study. Although the area is sown more than once increased from 16.94% in 1985- 1990 to 41.91% in 2000-05, it declined to 16.94% in 2015-19. In the same way, the total cropped area increased until 2000-05 at 96.65% to the total geographical area of the district; however, it declined to 70.43% in 2015-19. Similar to the nature of the land-use pattern in Kerala and Palakkad, the agricultural land-use pattern in the Wayanad district shows a continuous increase in the land put to non-agriculture purposes. Within the category of land that is not available for cultivation, such as total fallow land, all other categories such as barren and uncultivable land, permeant pastures and other grazing lands, land under miscellaneous tree crops, including cultivable wasteland, has declined for the period under study. The decline in this category of land may have contributed to the non-decline of the net sown area under cultivation, contributing to an expansion of cropping intensity despite the declining gross cropped area.

Table: 3.4 Land use Pattern in Wayanad

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-19
Land put to non-agriculture use	3.03	3.61	4.97	5.79	5.19	6.64	3.03
Net sown area	53.5	54.62	54.61	54.7	54.27	54.04	53.5
Area Sown more than one	16.94	32.18	38.81	41.91	35.59	26.77	16.94
Total cropped area	70.43	86.81	93.42	96.65	89.86	80.82	70.43
Cropping Intensity	131.6	158.9	171.1	176.7	165.6	149.6	131.6
Barren and uncultivable land	0.85	0.54	0.22	0.12	0.12	0.04	0.85
Permeant pastures and other grazing lands	0.04	0.04	0.02	0.02	0	0	0.04
Land under miscellaneous tree crops	1.32	1.03	0.59	0.28	0.06	0.02	1.32
Cultivable waste	2.44	1.42	0.93	0.59	0.57	0.47	2.44
fallow land other than current fallow	0.71	0.61	0.43	0.24	0.25	0.35	0.71
current fallow	0.94	0.94	1.05	0.83	0.63	0.98	0.94

Sources: Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures are in thousand hectares expressed as a proportion of the total geographical area of the Wayanad district.

3.4 Cropping Pattern in Kerala

This section analyses changes in Kerala's cropping pattern since 1985. The proportion of paddy, total food crops, total food grains, and non-food crops is calculated as the proportion to the gross cropped area of the Kerala state and is given in Table 3.5. The five-year averages for the period from 1985 to 2019 are measured. There have been significant changes in the cropping pattern in Kerala, from the production of basic paddy-based food grains to the coconut-driven non-food crops in particular. As a proportion to the gross cropped area of the state, the area under paddy, food grains, and total food crops has respectively declined from 19.54%, 20.67%, and 51.43% in 1985-90 to 7.65%, 7.80%, and 37.40% in 2015-19. The proportion of the area under coconut and other non-food crops to the state's gross cropped area has increased from 28.9 % and 48.56 % in 1985-90 to 30.69% and 62.7 % in 2015-19.

Table: 3.5 Cropping Pattern Changes in Kerala

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-2019
Paddy	19.54	17.22	13.81	11.09	9.42	8.45	7.65
Total Food Grins*	20.67	18.04	14.28	11.55	9.82	8.72	7.8
Coconut	28.09	29.03	30.16	30.5	31.1	29.29	30.69
Total Food Crops**	51.43	48.06	45.57	44.57	32.65	40.07	37.4
Total Non-Food Crops ***	48.56	51.23	54.42	55.43	56.14	59.93	62.7
Banana	0.67	0.79	0.96	1.59	1.99	2.07	2.32
Areca nut	2.1	2.21	2.49	3	3.55	3.68	3.84
Cardamom	1.99	1.44	1.42	1.38	1.39	1.52	1.55
Pepper	5.36	6.04	6.11	6.75	7.66	6.24	3.23
Tea	1.16	1.14	1.2	1.21	1.21	1.36	0.21
Coffee	2.36	2.74	2.79	2.87	2.87	3.14	2.99
Rubber	12.96	14.42	15.45	15.84	12.49	19.4	20.76
Total Plantation Crops *****	16.95	17.54	23.4	20.16	15.81	24.41	25.72

Sources: Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures are expressed as a proportion of the gross cropped area of Kerala state in hectares. * Total food grain include total grains and pulses such as paddy, cholama, jower, maise, millet, wheat, other grain, total cereals, red gram, gram, tur. ** total food crops include total food grains plus fruits, vegetables, tapioca, tubers. *** total non-food crops include oil seeds, fibre drugs and narcotics, plantation crops, etc. **** total plantation crops include tea, coffee, rubber, coco.

Within the non-food crops, the area under banana and areca nut has shown an increasing trend except cardamom and pepper. The area under banana and areca nut has increased from 0.67% and

2.10% in 1985-90 to 2.32% and 3.84% in 2015-19, whereas the area under cardamom decreased from 1.99% in 1985-90 to 1.55% in 2010-15. However, after increasing from 5.36% in 1985-90 to 7.66% in 2005-10, the area under pepper decreased to 3.23% in 2015-19. The area under total plantation crops to gross cropped area of the state increased from 16.95% in 1985-90 to 25.72% in 2015-19. The area under rubber constitutes major plantation crops in the state, which after decreasing from 12.96% in 1985-90 to 12.49% in 2005-10, increased to 20.76% in 2015-19. The area under tea and coffee in the state shows a similar pattern for the period under study. Both crops have increased their share of the total cropped area from 1.16% and 2.36% in 1985-90 to 1.36% and 3.14% in 2010-15. However, the area under both tea and coffee declined to 0.21% and 2.99% respectively in 2015-19. Various reasons have been attributed to changes in the cropping pattern from basic food crops to non-food crops. However, climate change factors may also play a role in the shifts in the cropping pattern in Kerala. The prolonged dry spell during the entire decades of 1980 has made a favorable condition for the growth of thermal-sensitive crops such as coconuts and other non-food crops in place of paddy-based food crops that are highly vulnerable to both climatic variabilities and socio-economic changes. Along with lesser variability of the area under coconut production to the gross cropped area, the increase in the total area under non-food crops has contributed to the changes in the agrarian economy of Kerala in favour of commercialisation.

3.4.1 Cropping Pattern Change in Palakkad

This section analyses the cropping pattern in Palakkad. Like Kerala's cropping pattern shifts, Palakkad district also experiences similar trends. In Palakkad, there are apparent shifts in the area under paddy-dominated food crops production to coconut-driven commercial crops cultivation. Although the share of area under paddy-based food grains and other foods crops shows declining over the period under study, the area devoted to producing basic food grains and other food crops still holds a prominent position. Palakkad is particularly vulnerable to climate change because a greater proportion of the area is still devoted to cultivating crops such as paddy, food grains, and other food crops that are highly exposed and sensitive to climate variabilities. Among commercial crops, the area under banana cultivation in Palakkad districts has consistently increased from 0.74 % Ha in 1985-90 to 5.71 % Ha in 2015-19 (Table 3.6). After an expansion from 0.73 % Ha in 1985-90 to 2.23 % Ha in 2005-10, the area under pepper cultivation declined to 0.88 % Ha in 2015-19. There has not been much expansion of area under cardamom cultivation in Palakkad districts, where the area under cardamom cultivation decreased from 1.04 % Ha in 1990-95 to 0.91 % Ha in 2015-19.

Table: 3.6 Cropping Pattern Change in Palakkad

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-19
Paddy	44.68	40.66	36.14	40.08	33.58	30.48	27.65
Total Food grins	49.44	45.25	39.7	42.35	35.4	32.26	28.3
Total food Crops	71.28	66.86	63.31	70.41	62	58.36	56.26
Total Plantation Crops	7.19	17.58	13.91	12.01	15.83	13.03	14.36
Total non-food crops	28.72	34.56	36.69	39.28	37.63	41.64	43.74
Pepper	0.73	1	1.28	1.78	2.23	1.9	0.88
Banana	0.74	0.91	1.21	2.37	3.29	3.93	5.71
Cardamom	0.97	1.04	0.92	0.99	0.84	0.88	0.91
Coffee	0.71	0.71	1.26	1.62	1.42	0.27	0.27
Tea	0.21	0.22	0.25	0.27	0.24	1.48	1.48
Areca nut	0.82	0.87	1.08	1.52	2.05	2.84	3.13
Rubber	6.23	7.21	8.28	10.08	8.2	11.24	11.24
Coconut	10.2	11.83	14.09	17.17	17.33	18.6	20.11

Sources: Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures are expressed as a proportion of the gross cropped area of Palakkad. * Total food grain include total grains and pulses such as paddy, cholama, jower, maise,millet, wheat, other grain, total cereals, red gram, gram, tur. ** total food crops include total food grains plus fruits, vegetables, tapioca, tubers. *** total non-food crops include oil seeds, fibre drugs and narcotics, plantation crops, **** total plantation crops include tea, coffee, rubber, coco.

Coffee, tea, areca nut, rubber, and coconut are the important plantation crops grown in the Palakkad districts. Over time, expansion in the share of area under coffee and tea cultivation is marginal, whereas area under areca nut, coconut, and rubber crops is expanded visibly. As per table 3.6, the area under coffee increased to 1.62 % Ha in 2000-05 from 0.71 % Ha in 1985-90; however, it declined to 0.27 % in 2015-19. At the same time, the area under tea cultivation increased from 0.21 % Ha in 1985-90 to 1.48 % Ha during 2010-15. The area under areca nut and coconut plantation shows continuous expansion of which both crops respectively increased from 0.82 % Ha and 10.2 % Ha in 1985-90 to 3.13 % Ha and 20.11 % Ha in 2015-19. In the case of rubber crops in Palakkad, the area under cultivation raised to 10.08 % Ha in 2000-05 from 6.23 % Ha in 1985-90. Although the area under rubber crops declined to 8.2 % Ha in 2005-10, it further increased to 11.24 % Ha in 2010-19.

3.4.2 Cropping Pattern in Wayanad

In contrast to the nature of the cropping pattern changes in Kerala state and the one depicted in the preceding section in the case of Palakkad, the agriculture economy of Wayanad district has different experiences. Paddy and other food crops not only constitute a lesser share of the total cropped area during periods under study but also consistently decreased. There was a time in Wayanad when entire fields of farms were devoted to cultivating paddy and other food grains; however, there were visible shifts in the area for the cultivation of non-food crops, predominantly plantation crops.

Table: 3.7 Cropping Pattern Changes in Wayanad

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-19
Paddy	13.83	11.15	9.36	7.07	5.61	6.63	5.87
Total Food Grains	14.06	11.32	9.54	7.23	5.84	6.84	6.19
Total Food Crops	48.07	49.49	51.12	52.9	40.3	45.17	41.33
Total Non-Food crops	51.93	50.51	48.88	47.1	46.17	54.83	58.73
Total Plantation Crops	44.93	45.12	44.75	41.57	38.48	45.03	48.73
Banana	00.0	1.05	1.76	4.88	5.81	5.61	6.79
Areca nut	0.98	1.28	2.1	3.06	5.00	6.09	6.82
Cardamom	2.84	2.64	2.29	2.00	1.96	2.21	2.36
Coconut	2.84	3.36	4.73	5.38	5.48	5.85	6.18
Coffee	38.33	37.12	35.04	32.81	32.08	36.37	39.13
Tea	3.56	2.93	2.85	2.88	2.75	3.42	3.25
Rubber	2.86	2.92	3.14	3.13	3.53	4.84	6.16
Pepper	15.18	18.61	19.5	20.76	19.29	11.23	5.36

Sources: Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures are expressed as a proportion of the gross cropped area of Wayanad. * Total food grain include total grains and pulses such as paddy, cholama, jower, maise, millet, wheat, other grain, total cereals, red gram, gram, tur. ** total food crops include total food grains plus fruits, vegetables, tapioca, tubers. *** total non-food crops include oil seeds, fibre drugs and narcotics, plantation crops,. **** total plantation crops include tea, coffee, rubber, coco.

More specifically, the area under total food crops dominantly paddy-based cropping pattern has decreased from 48.07 % Ha in 1985-90 to 41.33 % Ha in 2015-19 as a proportion to the district's total cropped area (Table 3.7). Although paddy and other food crops continuously decline their share, there has not been much decline in the area under total food grain cultivation. Lesser decrease in other important food crops contributed marginal decline in area under total food crops production. Wayanad agriculture area turned out to be cultivation for full of plantation crops and other non-food crops. Although, there has been small periodic ups and downs in the expansion of area under plantation crops and non-food crops for the period under study, while cultivation of plantation crops increased from 44.93 % Ha in 1985-90 to 48.73 % Ha in 2015-19, whereas cultivation of non-food crops increased from 51.93 % Ha in 1985-90 to 58.73 % Ha in 2015-19. The area under important commercial crops in Wayanad district shows an expansion in area under cultivation except for cardamom. There was an increase in the area under banana cultivation from 1.05 % Ha in 1990-95 to 6.79 % in 2015-19 (Table 3.7). The area under areca nut and coconut cultivation also show a similar expansion from 0.98 % Ha and 2.84 % Ha in 1985-90 to 6.82 % Ha and 6.18 % Ha, in 2015-19. At the same time, the area under cardamom cultivation decreased to 1.96 % Ha in 2005-10 from 2.84 % Ha in 1985-90 and stood at 2.36 % Ha in 2015-19. In contrast to the cropping pattern of plantation crops in Palakkad and Kerala, the cropping pattern of plantation crops in Wayanad districts is dominated by coffee cultivation followed by coconut and pepper cultivation. Plantation crops constitute 38.33 % Ha of the gross cropped area of Wayanad in 1985-90 declined to 32.08% Ha in 2005-10 and increased to 39.13 % Ha in 2015-19 (Table 3.7). The area under rubber cultivation in Wayanad is increased from 2.86% Ha in 1985-90 to 6.16% Ha in 2015-19. There is a drastic reduction in area under pepper cultivation in Wayanad from 15.18% Ha in 1985-90 to 5.36 in 2015-19, and the rate of decline has been sharp since the 2000s. The area under tea cultivation has not been expanded since 1985, more or less stagnant at 3.56% Ha in 1985-90 and stood at 3.25% Ha in 2015-19.

3.5 Cropping Intensity in Kerala, Wayanad and Palakkad

There is a significant increase in the double or multiple cropped area as a result of the “mixed cropping pattern, the availability of irrigation facilities, and other agricultural intensification measures” (DES, 2019) . Cropping intensity is calculated “to assess trends in intensity, which is the ratio of total cropped area to net cropped area”. Table 3.8 give an idea of the cropping intensity of Kerala, Wayanad and Palakkad. In the case of Kerala, cropping intensity decreased from 132.9 per cent in 1985-90 to 109.3 per cent in 1995-00, and in 2015-19, cropping intensity of the state was only 127.6 per cent. When compared to the entire study period, cropping intensity peaked between 2000 and 2005. Cropping intensity for the Wayanad in 1985-90 was 131.6 per cent, and it reached maximum to 176.7 per cent in 2000-05, and in 2015-19 it declined to 1985 level.

Cropping intensity for the Palakkad in 1985-90 was 149 per cent; it increased to 160.3 per cent in 2005-10; however, it declined to 140.22 per cent in 2015-19.

Table: 3.8 Cropping Intensity in Kerala, Wayanad and Palakkad

	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-19
Kerala	132.9	135.3	109.3	136.6	133.7	128.2	127.6
Wayanad	131.6	158.9	171.1	176.7	165.6	149.6	131.6
Palakkad	149.0	166.8	151.5	157.6	160.3	124.5	140.22

Source: Agriculture Statistics, Directorate of Economics and Statistics, Govt. of Kerala. Note: Values are expressed in the percentage of the ratio of net sown area to the gross cropped area.

3.6 Production of Important Crops in Kerala.

The present section is devoted to the analyses of growth in the production of important crops produced in Kerala state, Palakkad and Wayanad districts. The most important crops produced in the districts are rice, banana, tapioca, cardamom, areca nut, coconut, rubber, pepper, tea, and coffee. Table 3.9 give the annual compound growth rate of important crops produced in Kerala. It can be inferred from Table 3.9 that a negative growth rate is experienced for all crops except for tea and rubber, particularly for the period between 2000 and 2010.

Table: 3.9 Growth Rate of Important Crops in Kerala

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-2019
Rice	-0.55	-2.14	-4.16	-2.35	-1.03	1.46	1.51
Tapioca	1.68	-3.51	1.2	-1.49	-0.34	4.09	-0.11
Banana	5.3	3.83	2.52	-7.59	-3.75	2.43	3.33
Pepper	13.17	4.83	-4.53	-4.24	-13.49	-2.11	-1.21
Cardamom	-6.67	4.83	5.02	2.6	-2.28	-1.02	15.06
Coconut	6.71	4.75	1.96	-15.61	-2.18	-2.21	2.38
Areca nut	19.28	6.25	-2.94	4.64	-0.43	4.74	-1.1
Tea	1.64	-1.06	-0.89	-6.46	0.5	2.61	1.31
Coffee	-0.2	17.2	7.26	-5.1	-0.31	0.62	5.4
Rubber	8.33	7.55	3.84	3.56	0.17	6.1	-8.01

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures represent an annual compound growth rate of production in tonnes expressed in percentages.

Rice is, the crucial food crop produced in the state, experienced an increasing rate of negative growth from -0.55% in 1985-90 to -4.16% until 1995-00. However, the negative growth rate in rice production has declined to -1.03% in 2005-10. It has been noticed that 1.46 % growth rate of rice production in 2010-15 for the first time since 1985 in Kerala. This increase in rice production growth has been attributed to various promotion policies of rice cultivation by the state government and the adoption of specific adaptation strategies such as the System of Rice Intensification in various parts of the states. Although the growth rate of tapioca is subjected to periodic ups and downs, the growth rate has increased from 1.68% in 1985-90 to 4.09% in 2010-15. Except for a decade's negative growth rate of banana production during the 2000s, banana production in the state registered a decline in the growth rate from 5.3% in 1985-90 to 3.33 % in 2015-19. Nevertheless, the number of years of positive growth for banana production is greater than other basic food crops. Important commercial crops grown in Kerala are coconut, areca nut, banana, pepper, cardamom, pepper, rubber, tea, and coffee. It is clear from Table 3.9 that pepper production in the state experienced a drastic reduction in growth from 13.17% 1985-90 to negative growth of -13.49% and stood at the rate of -1.21% in 2015-19. There has been an impressive growth in cardamom production amid two few five years of negative growth. Specifically, the growth rate of cardamom increased from negative growth of -6.67% in 1985-90 to -1.02% in 2010-15, and further, it jumped to -15.06% in 2015-19. Another important commercial crop is the coconut. Its growth rate has drastically declined from 6.71% in 1985-90 to a negative growth of -15.61% in 2000-05 and stood at the growth rate at 2.38% in 2015-19. In the same way, areca nut production is also subject to a significant reduction in the growth rate from 19.28% in 1985-90 to a negative growth rate at -2.94% in 2000-05; however, the growth rate stood at -1.1% in 2015-19. Regarding the commercial crops, tea and coffee production's growth rate did not perform well. Although coffee production registered a higher growth rate of 17.2% in 1990-95, it eventually declined to 5.4 % growth in 2015-19. Even the growth rate of tea production registered a higher negative growth rate -6.46 % in 2000-05, and its growth rate increased from 1.46 % in 1985-90 to 1.31 % in 2015-19. However, after recording a decreasing but positive growth rate, the growth rate of rubber production significantly fell from 8.33% in 1985-90 to a negative growth rate of -8.01% in 2015-19.

3.6.1 Production of Important Crops in Palakkad

The growth pattern in rice production in the Palakkad district contrasts with the state pattern. When rice, banana and tapioca crops experienced negative growth during the entire 2000s in Kerala, Palakkad district had negative growth for all three crops only in the latter half of the 2000s. Although the number of negative growths recorded for rice production in Palakkad district is less than the one recorded in the state pattern, the growth rate of rice production in Palakkad declined from 3.1% in 1985-90 to -0.03% in 2005-10 and stood at the 2.2% growth in 2015-19, and this growth rate for Palakkad is still greater than the state average (Table 3.10). The growth rate of tapioca production is also declined drastically from 6.23% in 1985-90 to negative growth of -5.66% in 2000-05 and then reversed to the positive growth rate at 3.8% in 2015-19. In sharp contrast to the state-level average growth rate of banana production, the growth rate of banana production in Palakkad increased from 9.89% in 1958-90 to 16.35 in 2000-05 in Palakkad. The growth rate of bananas increased to 7.32 % in 2010-15 but declined to negative growth of -1.62 % in 2015-19.

Table: 3.10 Growth Rate of Important Crops in Palakkad

Years	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-2019
Rice	3.1	1.36	-2.84	-0.16	-0.03	1.62	2.2
Tapioca	6.23	2.36	-6.86	-5.66	-2.99	2.85	3.8
Banana	9.89	2.48	3.05	16.35	-0.63	7.32	-1.62
Pepper	9.54	10.91	4.13	10.63	-0.12	0.31	-1.2
Ginger	7.48	19.12	0.25	-10.76	1.1	-5.62	3.58
Cardamom	3.57	-2.28	-2.09	6.58	4.1	0	1
Cotton	10.87	14.03	-6.11	-17.52	-17.44	17.5	-0.05
Tea	2.29	3.78	1.6	-2.23	-4.32	10.1	3.7
Coffee	38.86	13.33	0.4	1.53	-4.43	4.52	-2.45
Rubber	18.14	7.26	6.1	6.52	-1.31	-7.54	-4.8
Areca nut	7.88	21.99	6.96	16.92	12.93	-1.72	6.2
Coconut	18.13	-13.35	-2.75	9.57	0.1	1.61	11

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures represent an annual compound growth production rate in tonnes expressed in percentages.

It has been observed that all commercial crops have experienced a negative growth rate, especially after 2000, except cardamom. Another feature of the growth pattern of commercial crops in the Palakkad district is that the growth rate of all crops except cotton decreased for the period under study. Although the growth rate and the number of years of negative growth rate are greatest for cotton, there has been a sharp improvement in the growth rate performance, especially since 2010. The growth rate of pepper production increased from 9.54% in 1985-90 to 10.63% in 2000-05. After registered negative growth rate at -0.12% in 2005-10, it stood at -1.2 % in 2015-19. Ginger production also recorded a high growth rate of 19.12% in 1990-95. However, it sharply reduced to -10.76% in 2000-05 and increased to 3.58 % in 2015-19. The growth rate of cardamom production was 3.57% in 1985-90. However, before registering the highest growth rate for the period under study at 6.58 in 2000-05, it underwent a decade of negative growth since 1990. Cardamom production has been declined since then from 4.1% in 2005-10 and recorded no growth in 2010-14. In 2015-19, the cardamom growth rate was just 1 per cent. Important plantation crops grown in the Palakkad district are tea, coffee, rubber, areca nut, and coconut. The district does not show any regularity in its growth pattern for the period under study. However, all plantation crops have been subject to a significant reduction in growth rate since 1985 except tea production. Amid negative growth for a decade since 2000, the growth rate of tea increased from 2.29% in 1985-90 to 10.1% in 2010-15. The growth rate of coffee, rubber and coconut production respectively fell drastically from 38.86%, 18.14%, and 18.3% in 1985-90 to --2.45 %, -4.8 %, and 11 % in 2015-19. The decline in the growth rate of areca nut production has been relatively less than other plantation crops; however, after increasing its growth rate from 7.88% in 1985-90 to 16.92 % in 2000-05, it declined to a negative growth rate at -1.72% in 2010-15, however again increased to 6.2 % in 2015-19.

3.6.2 Production of Important Crops in Wayanad.

The growth pattern of rice, banana and tapioca production in the Wayanad district shows a distinct picture in contrast to the Kerala state averages and the one shown above in the case of Palakkad district. The number of negative growth years recorded regarding these crops in the Wayanad district is comparatively less than the other two cases. The growth rate of rice production in Wayanad increased from -4.78% in 1985-90 to 3.16% in 2005-10 (Table 3.11). However, it declined to -1.21% in 2015-19. Unlike the other two cases, the growth rate of banana production has been drastically declined from 20.28% in 1985-90 to 3.2 % in 2015-19. Similarly, the growth rate of tapioca in Wayanad increased from 2.45 % in 1990-95 to 10.85 % in 2000-05, drastically declined to -6.1 % in 2015-19. Unlike the number of negative growth years recorded concerning important commercial crops and plantation crops in the case of Kerala and Palakkad, Wayanad district recorded less negative growth concerning those crops. In the Wayanad district, a sharp reduction in ginger production from 14.91 % in 1985-90 to -10.75 % in 2010-15. In 2015-19, the growth rate of ginger was 5.07 %. Cardamom and coconut production has not been registered any negative growth rate for the period under study. However, when the growth rate of cardamom production increased from 5.76% in 1985-90 to 12.2% in 2010-15, and later declined to 1.25 % in

2015-19. The growth of coconut production decreased from 14.87% in 1985-90 to 3.3 % in 2015-19. The growth pattern of pepper and areca nut production

Table: 3.11 Growth Rate of Important Crops in Wayanad

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-2019
Rice	-4.78	1.28	2.63	-2.88	3.16	-1.28	-1.21
Banana	20.28	14.41	3.04	9.85	-9.06	2.66	3.02
Tapioca	---	2.45	7.79	10.85	-1.19	-3.45	-6.1
Ginger	14.91	-3.18	1.38	9.06	13.84	-10.75	5.07
Cardamom	5.76	8.08	10.4	6.67	1.25	12.2	1.25
Pepper	20.62	8.57	10.4	-4.95	-17.1	14.55	-3.2
Areca nut	----	28.59	5.6	16.17	-2.25	-2.98	-5.4
Coconut	14.87	24.67	7.28	0	3.9	2.96	3.3
Tea	-2.6	1.81	-0.9	1	-4.84	10.51	7.2
Coffee	4.1	18.11	5.22	-1	-0.03	0.5	4.1
Rubber	2.93	2.63	4.4	11.07	4.56	-4.63	5.6

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures represent an annual compound growth rate of production in tonnes expressed in percentages.

in Wayanad district followed the same pattern that of Kerala and Palakkad district, where the growth rate of pepper in Wayanad has been declined from 20.62 in 1985-90 % to -17.1 % in 2005-10 and stood at -3.2 % in 2015-19. In comparison, the growth rate of areca nut declined from 28.59 % in 1990-95 to -5.4 % in 2015-19. Wayanad district is famous for producing plantation crops such as tea, coffee, and rubber to a lesser extent. However, Wayanad districts could not maintain their stable growth pattern of plantation crops. The growth rate of tea production in the Wayanad district was subject to a greater growth rate until 2010 and finally recorded a growth rate of 10.51% in 2010-15. In 2015-19, the growth rate of tea in Wayanad was 7.2 % only. Coffee is the most important plantation crop in Wayanad district, showing an increase in its growth rate from 4.1% in 1985-90 to 18.11 in 1990-95. However, it never regained its earlier position at a higher growth rate. The growth rate of coffee in Wayanad in 2015-19 was 4.1 %. In the case of rubber, after recording an increase in the growth rate of 11.07% in 2000-05 from 2.93% in 1985-90, it declined to 5.6 % in 2015-19.

3.7 Productivity of Important crops in Kerala.

This section deals with the analysis of the productivity growth of important crops grown in Kerala, Palakkad, and Wayanad. Productivity is measured as the yield of kilogram per hectare of crops given in Table 3.12. The growth in rice, tapioca, and banana yields shows no regular growth rate pattern, which indicates periodic variability of climatic and non-climatic factors. After periodic ups and downs, the rice yield growth rate marginally increased from 3.13 % in 1985-90 to 4.2 % in 2015-19 (Table 3.12). Tapioca has been another important substitute of food crops also decreased its productivity by half times in growth rate from 8.33% in 1985-90 to 1.02 % in 2015-19. In contrast, the productivity growth of bananas increased from -7.32 % in 1985-90 to 2.49 % in 2000-05. However, it decreased by 2.5 % in 2015-19.

Table: 3.12 Growth in Yield of Important Crops in Kerala.

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-2019
Rice	3.13	-0.06	2.16	1.56	2.85	3.71	4.2
Tapioca	8.33	1.89	-0.50	4.85	4.41	4.01	1.02
Banana	-7.32	0.29	-6.57	2.49	-0.27	1.66	2.5
Pepper	7.80	3.39	-6.11	1.15	-9.44	16.02	2.03
Ginger	6.17	2.66	0.81	5.38	3.53	-3.19	5.6
Cardamom	-10.39	5.13	6.88	3.20	-5.59	20.28	5.1
Coconut	3.40	5.05	2.16	-18.52	0.81	2.22	2.67
Areca nut	21.32	-9.26	-5.29	0.47	-2.31	6.81	0.25
Tea	2.17	-1.34	0.27	-6.84	-0.63	8.62	-0.2
Coffee	-3.54	19.15	8.57	-6.31	-0.43	0.65	6.1
Rubber	5.30	7.51	3.47	3.82	-1.30	-10.56	2.2

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures represent an annual compound growth rate of yield per hectare expressed in percentages.

Productivity of important commercial crops also shows no regular pattern in growth rate. Pepper, ginger, and cardamom crops have consistently shown variability in their productivity growth pattern for the period under study. Although productivity growth of pepper increased by more than half time from 7.80 % in 1985-90 to 16.02 % in 2010-15, the productivity growth of pepper has been subjected to an increasingly higher rate of negative growth rate at -6.11% and -9.44% in 1995-00 and 2005-10, respectively. In the middle of a greater level of variability in growth pattern, the growth rate of ginger productivity decreased by more than three times from 6.17% in 1985-90 to -3.19% in 2010-15. It also holds in the case of cardamom productivity, although amid greater variability. The productivity growth of cardamom had increased by more than three times, from -10.39% in 1985-90 to 20.28% in 2010-15. The growth rate of cardamom in Kerala in 2015-19 was 5.1 % only. Important plantation crops are grown in Kerala, including coconut, areca nut, tea, coffee, and rubber, also declined in productivity growth except for tea and coffee. Coconut's productivity growth declined by more than six times from 3.40% in 1985-90 to -18.52% in 2000-05, and marginally increased by 2.67 % in 2015-19. After registering a 21.32% growth rate for areca nut productivity in 1985-90, and consistent years of negative growth until 2005-10, the growth rate of areca nut productivity stood at 0.25 % in 2015-19. The growth rate of rubber productivity also decreased by three times from 5.30 % in 1985-90 to -10.56% in 2010-15. The growth rate of rubber yield was 2.2 % in 2015-19. In contrast, the productivity growth rate of tea and coffee has respectively increased from 2.17% and -3.54% in 1958- 90 to 8.6% and 0.56% in 2010-15. The yield growth of tea and coffee in 2015-19 was -0.2 % and 6.1 %, respectively.

3.7.1 Productivity of Important Crops in Palakkad

The growth in yield per hectare of rice, tapioca, and banana in the Palakkad district has shown a similar pattern to Kerala. The productivity of rice and tapioca respectively decreased by more than half times from 6.05% and 5% in 1985-90 to 3.6 % and 1.4 % in 2015-19 (Table 3.13). Between 1985 and 2019, rice productivity in Palakkad experienced variability in growth rates. At the same time, the productivity growth of bananas in Palakkad increased from 1.80 % in 1985-90 to 4.2 % in 2015-19. This marginal increase in growth was registered after the sharp reduction of productivity growth to -6.03 % in 1995-00 and increase in productivity growth to 4.25 % in 2000-05. The yield growth per hectare of commercial crops such as pepper and cotton in Palakkad increased sharply after greater variability in its growth rates during the period under study, whereas in contrast, the productivity growth of ginger and cardamom after the periodic ups and downs has declined. Yield per hectare of pepper and cotton has respectively increased from -3.94% and zero% in 1985-90 to 11.2% and 10.2 % in 2010-15. Conversely, the productivity of ginger and cardamom after the great variability has respectively decreased from 1% and 5.45% in 1985-90 to -2.1 % and 2.5 % in 2015-19. The yield growth of plantation crops, such as coffee, decreased from 45.62 % in 1985-90 to -2.61 % in 2015-19, whereas tea registered a yield growth for the same period from 4.31 % to 8.4 %, respectively. Incongruent to the decline in productivity growth of Kerala, the productivity growth of areca nut, coconut, and rubber in Palakkad in terms of yield per Ha has been respectively declined from 3.72%, 13.21% and 23.17 % in 1985-90 to -0.02 %, 7.2 % and 4.6 % in 2015-19.

Table: 3.13 Growth in Yield of Important Crops in Palakkad.

Crops	**1985-90**	**1990-95**	**1995-00**	**2000-05**	**2005-10**	**2010-15**	2015-2019
Rice	6.05	0.18	0.71	1.48	3.14	3.41	3.6
Tapioca	5.00	3.88	-0.79	4.36	4.80	2.00	1.4
Banana	1.80	-0.94	-6.03	4.25	0.71	2.13	4.2
Pepper	-3.94	4.55	0.23	2.76	6.51	19.80	11.2
Ginger	1.00	10.17	-2.73	-3.24	15.37	-4.69	-2.1
Cardamom	5.45	-0.57	0.56	9.82	5.14	-0.01	2.5
Cotton	0.00	-1.05	0.00	-0.06	0.01	14.09	10.02
Areca nut	3.72	-17.74	-6.29	-8.61	-3.73	0.52	-0.02
Coconut	13.21	38.48	-16.59	7.14	-0.65	0.48	7.2
Tea	4.31	-0.19	1.61	-2.79	-5.37	13.48	8.4
Coffee	45.62	15.10	-1.61	0.35	-8.00	4.71	-2.61
Rubber	23.17	8.33	11.18	7.06	-0.46	-8.99	4.6

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures represent an annual compound growth rate yield per hectare expressed in percentages.

3.7.2 Productivity of Important Crops in Wayanad

Productivity growth of rice, tapioca, and banana in terms of yield per Ha in Wayanad show a different pattern than that of Kerala and Palakkad. The rice's productivity growth has been slightly increased from 1.96 % in 1985-90 to 2.2 % in 2015-19 after recording an increase to 3.94 % 1995-00, nevertheless variability in growth of yield per Ha in Wayanad is less as compared to Palakkad (Table 3.14). Tapioca's productivity growth has consistently recorded negative growth amidst higher variability until 2005-09. However, it increased from -12.15 % in 1985-90 to -0.61 % in 2015-16. Growth of yield per Ha of banana slightly decreased its negative growth from -3.72 % in 1985-90 to -2.65 in 2010-15, after recorded higher positive growth at 8.48 % in 1995-00. These indicate that yield per Ha of tapioca and banana in Wayanad has been subjected to higher variability. Pepper, ginger, and cardamom are the important commercial crops grown in Wayanad, of which growth in yield per Ha shows greater variability in its growth pattern for the period under study. The growth rate in yield per Ha of ginger and cardamom of Wayanad is similar to that of

Kerala, whereas different pattern in the case of pepper. Growth in yield per Ha of ginger is similar in all cases; however, growth in yield per Ha of pepper and cardamom in Wayanad followed a different pattern concerning Palakkad. After a long period of consistent positive growth until 2010, growth in yield per Ha of pepper drastically decreased by more than three times from 16.77 % in 1990-95 to 3.5 % in 2015-19. Similarly, after recording a greater variability, growth in yield per Ha of ginger declined in its growth rate by more than double from 7.54 % in 1985-90 to -3.1% in 2015-19. In contrast, yield per Ha of cardamom grew from -8.88 % in 1985-90 to 15.41 % in 2010-15, nevertheless subjected to greater variability.Wayanad district is famous for plantation crops cultivation in both area and production. Despite thermal and excess moister resistant feature of such crops, decline and variability in its growth of yield per Ha have been noted for coconut, tea, and rubber, whereas areca nut and coffee has been marginally increased. Growth in yield per Ha of areca nut and coffee has respectively increased marginally from 5.73 % and -8.12 % in 1985-90 to 8.4 % and 11.2 % in 2015-19. In the case of other plantation crops such as coconut and rubber; its yield growth respectively decreased from 14.92 % and 20.28 % in 1985-90 to 6.4 % and 6.7 % in 2015-19, whereas for tea, its yield growth increased from -0.35 % in 1985-90 to 9.4 % in 2015.19.

Table: 3.14 Growth in Yield of Important Crops in Wayanad.

Crops	1985-90	1990-95	1995-00	2000-05	2005-10	2010-15	2015-2019
Rice	1.96	1.80	3.94	0.29	0.84	1.69	2.2
Tapioca	-12.15	-2.69	-3.21	16.61	-6.39	5.19	-0.61
Banana	-3.72	-0.79	8.48	-12.31	1.02	-2.65	1.2
Pepper	0.65	16.77	3.57	9.34	4.39	-9.49	3.5
Ginger	7.54	3.34	0.18	-24.45	9.00	-5.84	-3.1
Cardamom	-8.88	-6.22	6.53	-23.92	-0.93	15.41	6.1
Areca nut	5.73	-9.20	3.61	51.47	3.77	6.64	8.4
Coconut	14.92	12.09	1.44	-27.23	8.13	2.99	6.4
Tea	-0.35	-1.86	1.31	11.86	10.22	-15.37	9.4
Coffee	-8.12	19.54	6.44	4.15	-0.01	0.63	11.2
Rubber	20.28	-0.38	2.38	-28.55	-0.01	-7.37	6.7

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: All figures represent an annual compound growth rate yield per hectare expressed in percentages.

3.8 Status of Paddy Cultivation Kerala

Paddy cultivation is an integral part of the culture of the Kerala state. It is also the main food grain crop of the state. For a long period, paddy cultivation has been connected with the culture and festival of Kerala. It is the main agricultural activity, particularly in Kerala's coastal and midland wet fields. However, the area and production of paddy cultivation continue to decline over the years. Despite Kerala achieving self-sufficiency in rice production in 1972-73, the area and production of paddy have declined at an alarming rate in the latter year. At present, “Kerala state has a shortage of around 83.45 % of rice” (Karunakaran, 2014). Declining profitability forces cultivates to move away from paddy cultivation. The lucrative construction sector with high job opportunities and higher wages attracts more labour from paddy cultivation. The booming of the real estate and construction sector due to high foreign remittance to the state leads to the conversion of wet paddy land to non-agriculture purposes. This section is devoted to the analysis of the status of paddy cultivation in Kerala and comparative analysis of the same concerning the Wayanad and Palakkad districts.

3.8.1 Area under Food Grain and Paddy

Kerala has unique and diverse agroclimatic features, which helps it to cultivate different types of crops. In the past, agronomic conditions of land and food crops constituted the prime factor in determining a major part of cultivated land. However, there has been a gradual shift from paddy-based Foodgrain crops to the plantation and non-food crops. At present, the cropping pattern in Kerala is dominated by non-food crops. Our analyses of changes in the cropping pattern between area under food crops and non-food crops show that, as a proportion to the total cropped area, the area under food crops fluctuated between 36 % and 55 % between 1990-2019, whereas for the same period, the area under non-food grain observed a gradual increase from 45 % to 63 %. The low profitability of the paddy cultivation coupled with the high cost of cultivation appears to have contributed to shifting paddy land to other crops (DES, Trivandrum). Changes in trends in the area under paddy and non-food crops over the years have shown that the paddy fields have been converted for various other crops and non-agricultural use. Changes in the cropping pattern between paddy and non-food crops in Kerala can be seen in Table 3.15. There has been a consistent decline in area under paddy cultivation in Kerala. The area under paddy cultivation declined by more than half from 23.1 % of total cropped area in 1990-91 to 11.5 % in 2000-01, further

Table: 3.15 Area Under Paddy Versus Non-Paddy Crops

Year	Paddy	Foodgrain crop	Food crops	Total Plantation Crops	Total Non-Food Crops
1990-91	23.1	24.3	55.4	16.1	44.6
1991-92	20.8	22.0	53.0	16.3	47.0
1992-93	19.5	20.7	51.9	16.7	48.1
1993-94	19.3	20.5	51.4	17.2	48.6
1990-91	18.5	19.5	49.5	17.7	50.5
1991-92	17.9	19.0	49.0	18.3	51.0
1992-93	17.6	18.7	48.3	18.8	51.7
1993-94	16.7	17.7	47.8	16.0	52.2
1994-95	16.7	15.8	46.6	18.0	53.4
1995-96	15.8	14.8	46.0	18.9	54.0
1996-97	14.5	14.3	45.6	19.4	54.3
1997-98	13.0	13.8	45.3	19.9	54.7
1998-99	12.1	12.7	44.4	20.5	55.6
1999-00	11.7	12.2	44.5	20.0	55.5
2000-01	11.5	11.9	44.6	20.0	55.4
2001-02	10.8	11.3	44.6	20.2	55.4
2002-03	10.5	10.9	44.5	20.4	55.5
2003-04	9.7	10.1	43.9	20.7	56.1
2004-05	9.7	10.1	44.0	20.6	55.2
2005-06	9.2	9.7	44.2	20.9	55.8
2006-07	9.0	9.4	42.5	21.7	57.5
2007-08	8.3	8.6	40.8	23.4	59.2
2008-09	8.7	9.0	40.1	24.3	59.9
2009-10	8.8	9.1	40.0	24.7	60.0
2010-11	8.1	8.3	39.3	25.3	60.7
2011-12	7.8	8.0	37.4	25.3	62.6
2012-13	7.6	7.7	37.3	25.8	62.7
2013-14	7.6	7.8	37.1	25.9	62.9
2014-15	7.5	7.7	37.4	25.9	62.6
2015-16	7.4	7.5	37.3	25.8	62.6
2016-17	6.6	6.7	36.6	26.3	63.4
2017-18	7.5	7.6	37.3	26.4	62.7
2018-19	7.9	8.0	36.7	26.7	63.2
2019-20	7.6	7.8	36.9	26.6	63.1

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Note: Figures expressed in percent to the total cropped area of the Kerala state.

declining to 7.6 % in 2019-20. A similar trend can be visible in the case of the area under food grain production. The total area under food grain declined by one-half from 24.3 % in 1990-91 to

11.9 % in 2000-01 and further declined to 7.8 % in 2019-20. Whereas area under plantation-based cash crops and non-food crops significantly increased during the period. Out of the total cropped area, the area under plantation and non-food crops respectively increased from 16.1 and 44.6 % in 1990-91 to 26.1 and 63.1 % in 2019-20.

Table 3.16 describe the area (in parenthesis) and production of paddy (000' M Tones) versus cash crops such as rubber and bananas, coconut. It can be inferred that area under paddy crops receives severe completion again that of cash crops such as banana, coconut and rubber where on the one hand, production area under paddy is continuedly declined, whereas cash crops such as banana, coconut, and rubber show increasing since 1990. The area under coconut increased from 28.8 in 1990-91 to 30.2 % in 2014-15. Followed by rubber, which increased by more than half to 21.3 % 2019-20. The area under banana also registered an increase during the period under study. In contrast, the area under paddy declined by more than threefold from 23.1 % to just 7.6 % in 2019-20. Production of rice decreased to 587 MT in 2019-20 from 1086 MT in 1990-91. The production of cash crops such as banana and rubber increased from 283 MT and 307 MT in 1990-91 to 606 MT and 551 MT in 2019-20. Production of coconut registered an increase from 4232 million nuts in 1990-91 to 7607 million nuts in 2019-20.

Table: 3.16 Area and Production of Paddy Versus Cash Crops

Crop/Year	1990-91	1995-96	2000-01	2005-06	2010-11	2015-16	2019-20
Paddy	1086 (23.1)	953 (15.8)	751 (11.5)	629 (9.2)	522 (8.1)	549 (7.5)	587 (7.6)
Banana	283 (0.7)	351 (0.9)	329 (1.5)	491 (2.1)	483 (2.1)	540 (2.4)1	606 (2.3)
Coconut	4232 (28.8)	5155 (30.4)	5536 (30.6)	6326 (30.1)	5287 (29.1)	5947 (30.2)	7607 (29.4)
Rubber	307 (13.6)	474 (14.9)	579 (15.7)	739 (16.6)	770 (20.2)	507 (21.0)	551 (21.3)

Sources: 1. Economic reviews from 1985 to 2014, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala. Paddy, rubber, and banana area values in 000' M tones, the area in 000' ha, Figures in parenthesis are % of the area to total cropped area of Kerala.

From the above analysis, it is also the fact that there is an enormous decline in the cultivation of paddy. The area under Paddy faces severe competition from that of rubber, coconut, and banana because, on the one hand, the area devoted to producing cash crops like rubber, coconut, banana is increasing; on the other hand, under paddy is shrinking. Unattractive prices to paddy producers, high cost of cultivation, acute labour shortage, and climatic variability may have contributed to the decline in area under paddy cultivation. Paddy cultivation in the state can increase when cultivators are assured with fair prices, attractive to the producers. However, “rice registered the lowest increase in average farm prices among major agricultural commodities” (Johnson, 2018 as cited in George et al.,2001). The state government is now unable to protect cultivating paddy farmers using quantitative restriction under multilateral trade agreement of WTO, significantly when trade liberalisation has increased price variability between cash crops and non-cash crops like paddy. Moreover, there is an urgent need to restrict the conversion of paddy land to non-agriculture use as it endangers paddy production in the state.

3.8.2 Area, Production, and Productivity of Paddy in Kerala

Rice is the staple food of the people of Kerala; however, paddy cultivation is witnessed a consistent decline since the 1980s. The continuous decline in the area under paddy cultivation and consequent reduction in its production has important implications for the social, economic, and ecological development of the state. Immediately after the formation of the state, the area under paddy cultivation increased remarkably from 768435 hectares in 1958-59 to 881466 in 1974-75 (Economic review). In 1974-75, the area under paddy had reached the highest at 30 % to the total cropped area. After that, paddy cultivation experienced a steady decline- from 793266 hectares in 1979-80 to 604082 hectares in 1987-88, 503290 hectares in 1994-95 and 310521 hectares in 2002-03. At present, there has been a reduction in more than 65 % area under paddy cultivation in the state compared to the 1990s. Now, concerning the area under rice production, it constitutes only 196870 hectares, which is just 7 % of the total cropped area, far behind the area under coconut and rubber cultivation.

Land use data for selected categories from 2006 to 2016 shows a significant change in land use, especially in the categories of agricultural fallow lands, seasonal crops, and paddy cultivation. In the ten years from 2006-2016, the permanent conversion of paddy land has increased by 135%. Paddy, which was once one of the state's most important crops, has seen its cultivable area shrink due to indiscriminate land conversion to other uses, often for non-agricultural purposes and the planting of unsuitable crops.

Table: 3.17 Land use and Cover Changes in Kerala

Land Use Type	Area, 2006 (km2)	Area, 2016 (km2)	Change (%)
Paddy Cultivating Land	2473.62	2173.7	-12.12
Paddy Converted to seasonal crop	169.45	237.91	40.4
Paddy Converted (Permanent)	917.74	2162.25	135.61
Agricultural Seasonal Crop	163.98	80.64	-50.82
Agricultural Mixed Crop	13401.27	12021.82	-10.3
Agricultural Perinnial Plantation Crop	5899.52	6479.99	9.84
Agricultual Fallow Land	1920.06	518.99	-72.97

Source: KSCSTE, Report of committee examine the causes of repeated extreme heavy rainfall events, subsequent floods and landslides and to recommend appropriate policy responses , submitted to State Planning Board, Govt of Kerala, 2019

Production of rice in Kerala registered a peak performance of 13.76 lakh million tons in 1972-73 (Economic Review, 1975). However, rice production recorded a continuous decline to 1141231 million tons in 1989-90 (Economic Review, 1992), and in 2015-16 rice production in the state was only just 5.49 million tons. The decline in rice production has implications for the food security of the state. Kerala now has around an 85 % deficit in rice production, and Foodgrain produced in

Table: 3.18 Area, Production and Productivity of Paddy in Kerala

Year	Area, 000' ha	Production, 000' MT	Productivity, kg/ha	Year	Area, 000' ha	Production, 000' MT	Productivity, kg/ha
1990-91	559	1086	1942	**2005-06**	276	630	2283
1991-92	541	1060	1959	**2006-07**	264	642	2432
1992-93	537	1085	2020	**2007-08**	229	528	2306
1993-94	507	1004	1980	**2008-09**	234	590	2521
1994-95	503	975	1938	**2009-10**	234	598	2556
1995-96	471	953	2023	**2010-11**	213	522	2454
1996-97	431	871	2021	**2011-12**	208	568	2736
1997-98	387	765	1977	**2012-13**	197	508	2580
1998-99	353	727	2059	**2013-14**	199	564	2834
1999-00	350	771	2203	**2014-15**	198	562	2838
2000-01	347	751	2164	**2015-16**	196	549	2801
2001-02	322	704	2186	**2016-17**	171	436	2550
2002-03	311	689	2215	**2017-18**	194	521	2686
2003-04	287	570	1986	**2018-19**	198	578	2919
2004-05	290	667	2300	**2019-20**	198	587	2965

Sources: 1. Economic reviews from 1990 to 2019-20, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala.

the state accounts for only 15 % of its total food grain consumption (Thomas, 2011). Moreover, it will also contribute to an increase in unemployment and rural poverty. Reduction in land cover, reduction in water table/level, land quality, waterlogging, adverse effects on local microclimate, and weather are some of the other environmental implications of the decline in paddy production in the state. Seasonal shortage of labour supply, low level of profitability, high competition from other crops, high cost of cultivation, and the farmers' inability to adapt and cope climate variability perhaps reduced paddy production in the state.

Figure: 3.1 Area, Production and Productivity of Paddy in Kerala

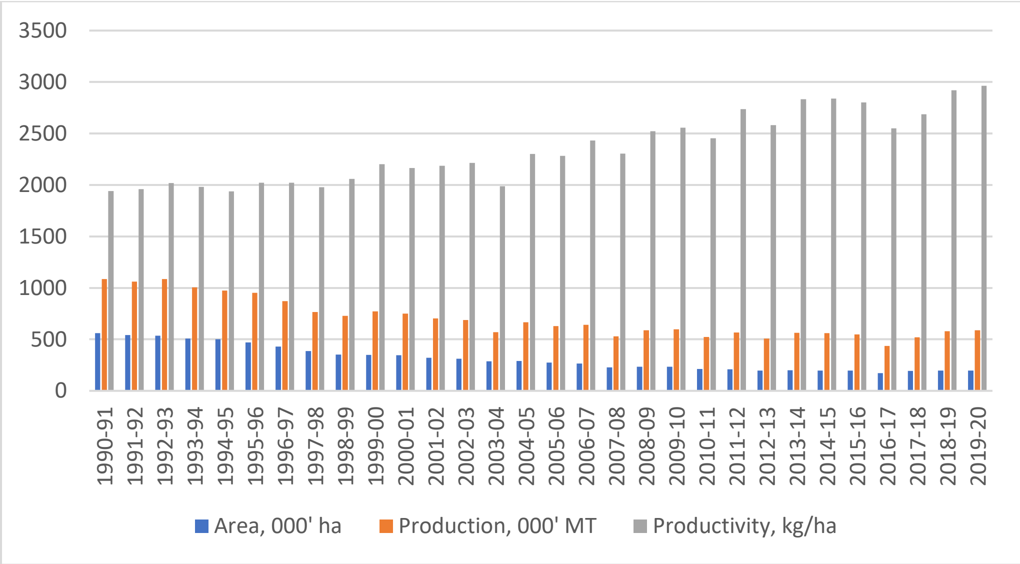


Figure:3.2 Area and Production of Paddy in Kerala

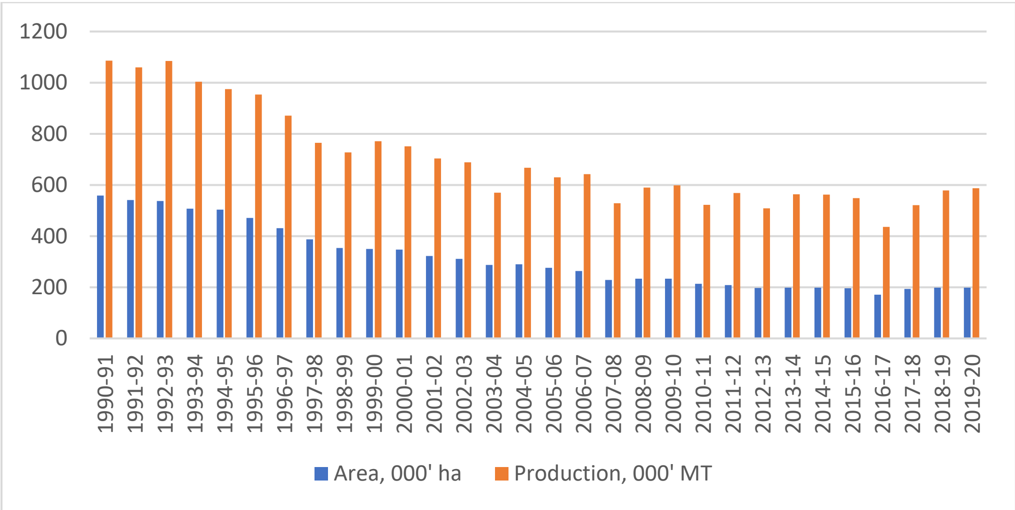
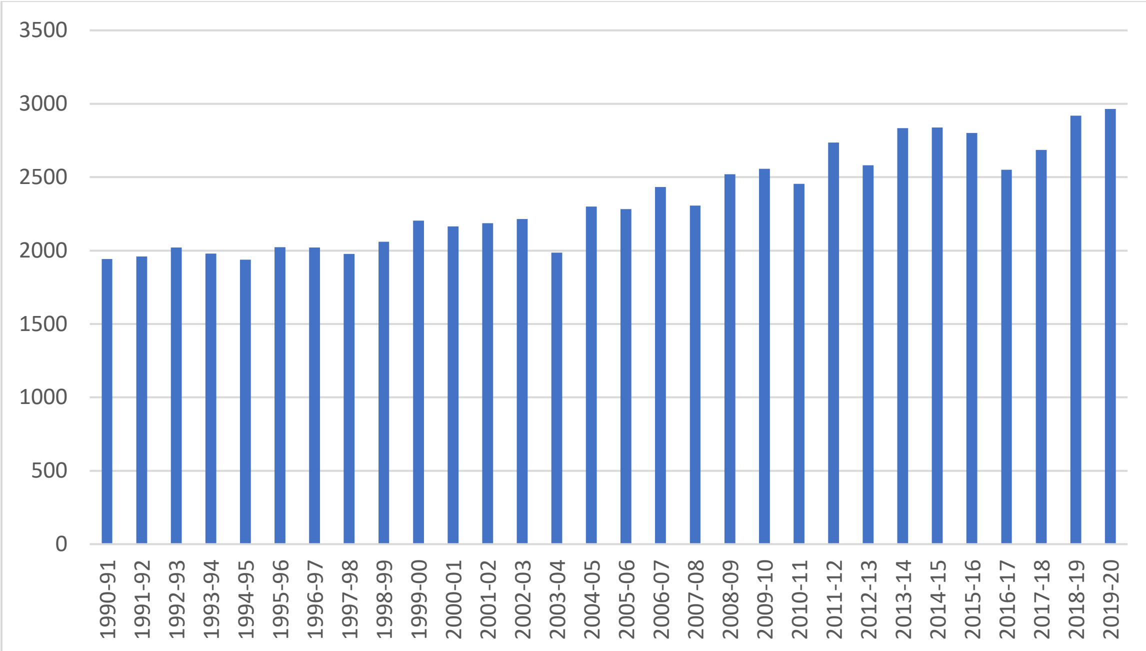


Figure: 3.3 Productivity of Paddy in Kerala, kg/ha



Although rice production and area under rice significantly declined over the years, rice productivity is showing an increase in the state. This fact shows the intensive cultivation of paddy in Kerala. The productivity of rice in Kerala has increased from K.g 1942 per hectare in 1990-91 to K.g 2834 per hectare in 2013-14. Despite rice productivity declining to K.g 2550 per hectare in 2016-17, the last year shows an increase in rice productivity to 2965 kg/ha in 2019-20. Although rice productivity in Kerala increased despite period fluctuation, the period since 2010 shows a discernable reversal in improvement in rice productivity.

Improvement in productivity in the state has been attributed to various efforts in soil health management, increased use of inputs from agriculture university, subsidies given to farmers under Rashtriya Krishi Vikas Yojana (RKVY), Sustainable Development Program in Agriculture (SDPA). Some of the initiatives taken during 2018-19 include “Rice Innovation Fund” (RIF). This program aims to new, eco-friendly, and sustainable technology in paddy cultivation. The focused intervention for paddy in seven “Special Agricultural Zones” (SAZ) introduced to Kuttanad, Onattukara, Pokkali, Kole, Palakkad, Wayanad, and Kaipad enhance production and productivity of paddy and increase farmers' income. Given the shrinking area and insufficient paddy production, the prospect of paddy cultivation in Kerala state lies in improving productivity with cost efficiency through the promotion of a “High-yielding Variety of Seeds” (HYVs). Therefore, productivity improvement in paddy must be by scientific management of paddy production to make it a remunerative enterprise for the farmers.

3.9 Value of Output of paddy

The performance of paddy production in the state largely depends on the price of paddy output. However, the profitability of paddy cultivation is relatively less due to the higher cost of cultivation of paddy coupled with low productivity compared to the other states of Kerala. One of the most important policy initiatives taken in agriculture price policy has been the inclusion of paddy production under the purview of Minimum Support Price (MSP).

Table: 3.19 Minimum Support Price for Paddy in Kerala

Year	Paddy price /Qntl	Year	Paddy price /Qntl	Year	Paddy price /Qntl
1990-91	297	**2001-02**	600	**2012-13**	1250
1991-92	385	**2002-03**	650	**2013-14**	1310
1992-93	421	**2003-04**	695	**2014-15**	1360
1993-94	410	**2004-05**	651	**2015-16**	1410
1994-95	511	**2005-06**	611	**2016-17**	1470
1995-96	523	**2006-07**	682	**2017-18**	1550
1996-97	609	**2007-08**	780	**2018-19**	1750
1997-98	545	**2008-09**	916	**2019-20**	1815
1998-99	600	**2010-11**	1000	**2020-21**	1868
2000-01	646	**2011-12**	1080	**2021-22**	1940

Source: Fci Website, Source, FCI, Govt. of India Note: Price is Rs/qntl

In Kerala, the government announced the Minimum Support Price (MSP) was only 297 Rs per quintal in 1990. Since then, MSP for paddy increased only marginally. Even in 2000, MSP increased to Rs 646 per quintal. Although farmers get an MSP of 1868 Rs per quintal, this price is not remunerative enough for the family households depending entirely on agriculture. The MSP announced by the Govt of Kerala for paddy crops since 1990 can be seen in Table: 3.19.

3.10 Area, Production, and Productivity of Paddy in Palakkad and Wayanad

Table 3.20 depicts the performance of paddy cultivation in Palakkad and Wayanad districts since 1990. Similar to the declining trend observed for all over Kerala concerning production and area under paddy, the performance of paddy in Palakkad district shows a different trend. Palakkad district is called the 'rice bowl of Kerala' because of the highest rank in both areas and paddy production in Kerala. In 1990, Palakkad had area and production of paddy respectively at 26 % and

Table: 3.20 Productivity of Paddy in Wayanad and Palakkad District

Year	The area under paddy (Ha)		Production of paddy 000’		Productivity Ha	
	Palakkad	Wayanad	Palakkad	Wayanad	Palakkad	Wayanad
1990-91	145687(26.0)	20343(3.6)	324907(29.9)	41974(3.9)	2230	2063
1991-92	147066(27.2)	19582(3.6)	344738(23.5)	42803(4.0)	2344	2186
1992-93	146095(27.2)	21135(3.9)	335646(30.9)	50337(4.6)	2297	2382
1993-94	143169(28.2)	20946(4.1)	334611(33.3)	46609(4.6)	2337	2225
1994-95	140066(27.8)	23772(4.7)	313718(32.2)	50492(5.2)	2240	2124
1995-96	135630(28.8)	20388(4.3)	280405(29.4)	46654(4.9)	2067	2288
1996-97	128359(29.8)	17078(4.0)	294065(33.8)	37563(4.3)	2291	2199
1997-98	120809(31.2)	17926(4.6)	262494(34.3)	39733(5.2)	2173	2217
1998-99	107467(30.4)	15642(4.4)	237788(32.7)	34689(4.8)	2213	2218
1999-00	109704(31.4)	17304(4.9)	250911(32.5)	44761(5.8)	2287	2587
2000-01	118701(34.2)	15000(4.3)	262173(34.9)	33802(4.5)	2209	2253
2001-02	115904(33.9)	12855(4.0)	269302(38.3)	32076(4.6)	2323	2495
2002-03	115910(33.3)	12988(4.2)	243926(35.4)	31326(4.5)	2104	2412
2003-04	105131(33.2)	12343(4.3)	189443(33.2)	28421(5.0)	1802	2303
2004-05	111029(33.8)	11331(3.9)	260118(39.0)	29206(4.4)	2343	2578
2005-06	113919(32.5)	11503(4.2)	266634(42.3)	28385(4.5)	2341	2468
2006-07	109208(31.1)	11832(4.5)	270103(42.1)	30722(4.8)	2473	2597
2007-08	99173(30.6)	12408(5.4)	244244(46.3)	32079(6.1)	2463	2585
2008-09	96190(30.5)	12746(4.5)	240143(40.7)	33861(5.7)	2499	2657
2009-10	100522(32.1)	12995(5.6)	266231(44.5)	33157(5.5)	2648	2552
2010-11	87511(27.6)	11054(5.2)	218155(41.7)	27912(5.3)	2493	2525
2011-12	83998(47.9)	8995(4.3)	224413(39.1)	23526(4.1)	2672	2615
2012-13	79201(27.5)	10230(5.2)	189229(37.2)	28052(5.5)	2389	2742
2013-14	81008(27.8)	11481(5.8)	238065(42.2)	30755(5.5)	2872	2679
2014-15	82912(27.6)	9690(4.9)	236398(42.1)	26168(4.7)	2851	2701
2015-16	81120(28.2)	9204(4.7)	228459(41.6)	23704(4.3)	2816	2575
2016-17	65512(23.7)	7822(4.6)	144275(33.1)	20647(4.7)	2202	2640
2017-18	75275(27.8)	8026(4.1)	198626(38.1)	21792(4.2)	2634	2715
2018-19	76942(28.3)	7761(3.9)	215285(37.2)	22340(3.9)	2792	2878
2019-20	76961(27.8)	7326(3.7)	248199(42.3)	19513(3.3)	3224	2663

Sources: 1. Economic reviews from 1990 to 2020, Planning and Economic Affairs Department, Government of Kerala. 2. Agriculture Statistics, Directorate of Economics and Statistics, Government of Kerala . Paddy production values expressed in 000' , area in ha. Figures in parenthesis are % to total area and production of Kerala.

29.3 % to state area and production. Area and production of paddy in Palakkad have respectively increased to 34.2 % and 34.9 % in 2000-01. In 2019-20, this further increased to 38.8 % and 42.3 %, respectively. However, Wayanad district has observed a similar trend to Kerala in terms of paddy area and production since 1990. In 1990, Wayanad had area and production of paddy at 3.6 % and 3.9 % to state area and production. Area and production of paddy in Wayanad has stagnated between 3 to 6 % throughout the period under study.

3.11 Costs of Cultivation of Paddy in Kerala

Table 3.21 shows the cost of paddy cultivation in Rs/Ha in Kerala since 2000. The total cost of paddy production is calculated by horizontal summation of the cost of cultivation in three seasons.

Table: 3.21 Cost of Cultivation of Paddy in Kerala (Rs/Ha)

Year	Hired Human Labour (Man Days)	Animal Labour(hr)	Machine labour(hr)	Seed(kg)	Manure(kg)	Total Cost
2000	9957.3(29.5)	532.3(1.6)	1661.7(4.9)	1053.3(3.1)	2435.3(7.2)	32100
2001	11242.0(29.8)	546.0(1.4)	2060.3(5.5)	1109.0(2.9)	2642.3(7.0)	33791
2002	10297.0(24.5)	449.7(1.1)	1918.0(4.6)	1201.0(2.9)	2475.3(5.9)	37701
2003	9868.7(23.0)	359.7(0.8)	2180.3(5.1)	1200.7(2.8)	2912.3(6.8)	42112
2004	9727.0(23.5)	392.3(0.9)	2418.7(5.9)	1148.3(2.8)	2715.7(6.6)	42871
2005	9866.7(23.1)	380.7(0.9)	2311.7(5.4)	1050.7(2.5)	2967.7(7.0)	41315
2006	11447.3(22.6)	227.7(0.4)	2645.0(5.2)	1133.3(2.2)	3025.7(6.0)	42645
2007	11678.0(20.2)	232.0(0.4)	3155.0(5.5)	1207.0(2.1)	3161.3(5.5)	50725
2008	13611.0(17.6)	242.3(0.3)	4080.3(5.3)	1372.7(1.8)	3095.7(4.0)	57771
2009	14975.7(11.6)	180.3(0.1)	4987.3(3.8)	1596.3(2.6)	3373.3(2.6)	77308
2010	18082.0(17.5)	221.7(0.1)	6472.7(6.3)	1779.0(1.7)	3888.7(3.8)	129659
2011	19795.0(19.2)	115.0(0.1)	4459.7(4.3)	1698.0(1.7)	4076.0(4.0)	103338
2012	19924.7(17.9)	137.0(0.1)	5928.0(5.3)	2100.7(1.9)	5380.0(4.8)	102879
2013	27658.3(20.5)	87.0(0.1)	6065.3(4.5)	2402.0(1.8)	6381.3(4.7)	111554
2014	27546.7(24.2)	79.0(0.1)	8789.3(7.7)	2525.3(2.2)	5487.7(4.8)	134681
2015	24722.3(23.1)	63.0(0.1)	10270.0(9.8)	2681.7(2.6)	6456.3(6.2)	113953
2016	24238.0(21.5)	240.7(0.2)	10248.7(9.1)	2878.0(2.5)	6846.3(6.1)	104276
2017	25321.7(11.3)	10.7(0.0)	8039.3(3.6)	2988.0(1.3)	7029.7(3.1)	112918
2018	28279.3(11.3)	19.3(0.0)	7795.0(3.1)	3317.3(1.3)	7949.7(3.2)	224591

Source: DES, Govt. of Kerala, cost of various cultivation reports. Figures in parenthesis represent a share in the total cost of cultivation

The analysis shows that the total cost of paddy cultivation has increased since 2000. Individual cost-share also shows different trends. Share of hired human labour cost constitutes 29.5 % of the total cost of cultivation in Kerala. It declined from 29.5 % in 2000-01 to 11.3 % in 2018-19. Though the share of machine labour increased from 4.9 % in 2000 to 9.8 % in 2015, however, declined to 3.1 % in 2018-19. Analysis shows that the share of animal labour is marginal and declined throughout the period from 1.6 % in 2000 to zero % in 2018-19, whereas the share of farmyard manure and chemical fertiliser also decreased from 7.2 % in 2000 to 3.2 % in 2018-19.

3.11.1 Cost Efficiency of Paddy Cultivation in Kerala

The last section of the present chapter attempted to understand the performance of paddy cultivation in Kerala in terms of the cost of production of paddy. Cost efficiency of paddy production in Kerala since 2000 for 19 years is analysed with a stochastic frontier production function. The stochastic frontier model is used for the estimation of parameters. An input-oriented technical efficiency model is assumed because where the given level of output is produced in the year from the least possible input costs. Estimated coefficients for cost efficiency are given in table 3.22.

The estimated coefficient for animal labour, seed, and manure is negative. The estimated coefficient for animal labour is -0.05 at the 1 % level of significance. Therefore, the present study shows cost inefficiency of paddy cultivation in Kerala has increased since 2000. High maintenance cost, shortage of skilled operation of animals in the fields perhaps increased inefficiency of the animal labour in the paddy cultivation in Kerala. The estimated coefficient for the seed also shows negative (-0.18) and at the 1 % level of significance, which implies still there are paddy farmers in Kerala who lack adequate training and awareness about the required application of seed in the paddy fields. This fact is also confirmed from the primary data from the present field study where the majority of the farmers apply between 40-50 kg seeds/ha in the field, in a place where only 30 kg/ha of seeds is required.

The estimated coefficient for both organic and inorganic manure also shows negative (-0.04) at the 1 % level of significance, implying that excessive, inadequate, and unscientific use of manure in the field causes inefficiency. It is observed from the primary data for the present study that many farmers apply organic and inorganic manure simultaneously. Potential benefits of applying manures constraints by the unscientific application of it in the paddy field by the farmers. Since most farmers apply both organic and inorganic manure together in the field, there is an urgent need to make aware farmers of the required interval between applying organic and inorganic manure to address inefficiencies that originates from these sources.

Table: 3.22 Estimate of Stochastic Frontier Model

```
Stoc. frontier normal/truncated-normal model    Number of obs     =         19
                                                Wald chi2(5)      =   7.38e+08
Log likelihood =  61.679215                     Prob > chi2       =     0.0000
```

yieldha	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
hiredhumanlabour	.250147	.0000965	2593.10	0.000	.2499579	.250336
animallabour	-.0549703	.0000202	-2725.67	0.000	-.0550098	-.0549308
machinelabour	.0360562	.0000866	416.42	0.000	.0358865	.0362259
seed	-.1805906	.0003458	-522.22	0.000	-.1812684	-.1799128
mannure	-.0413195	.0002864	-144.26	0.000	-.0418809	-.0407581
_cons	3.079228	.	.	.	.	.
/mu	-.5175613	.1281242	-4.04	0.000	-.76868	-.2664425
/lnsigma2	-4.859419	.0001407	-3.5e+04	0.000	-4.859694	-4.859143
/lgtgamma	31.46526	225.37	0.14	0.889	-410.2519	473.1824
sigma2	.007755	1.09e-06			.0077529	.0077571
gamma	1	4.85e-12			6.8e-179	1
sigma_u2	.007755	1.09e-06			.0077529	.0077571
sigma_v2	1.68e-16	3.78e-14			-7.40e-14	7.43e-14

The estimated coefficient for the hired human labour and machine labour is positive and significant at 0.25 and 0.036 at the 1 % level, which implies that the cost efficiency of paddy farming gets increased when farmers optimise these inputs. The utilisation of scarce labour resources remained with paddy cultivation after labour transfer to the employment guarantee program is a challenge; however, paddy cultivation in Kerala could maintain efficiency in using hired labour. Efficient use of machine labour is made possible in paddy cultivation because it is mainly carried out under the Padashekhara Samithi.[16]

[16] Padashekhara Samithi is a grassroot level organisation by the paddy farmers for the combined operation of paddy cultivation. Through smithies, many of the problems in paddy cultivation stems from labour shortage, machine shortage, information sharing etc are resolved. Samithies tries to intermediate farmers to public authorities to avail farmers various support services to paddy cultivation from government.

3.12 Conclusion

Before analysing the performance of paddy cultivation in Kerala, the performance of agriculture of Kerala from the crop sector is carried out in the present chapter. In this chapter, changes in the land-use pattern, cropping pattern, trend in the growth rate of production, and productivity of important agriculture crops of Kerala have been analysed. The same analyses from comparative perspectives have also been done concerning Kerala's Palakkad and Wayanad districts. It has been found that there have been tremendous changes in the land-use pattern in Kerala for the period under study. Agriculture land has been increasingly used for non-agriculture purposes. The net sown area has not been expanded.

On the one hand, climate change factors have led to select a crop mix by farmers that are either thermal or climate-resistant crops, mainly perennial crops in nature. On the other hand, such a selection of cropping patterns could not contribute to the expansion of the net sown area. Deficiency in rainfall patterns in the post-monsoon season forces the farmers to follow adaptation practices that enable them to overcome climate change risks of what is known as "strategic adaptation practices". In this adaptation process, gross cropped areas did not increase due to a decline in the area sown more than once. Similar trends in the changes in the land-use pattern in Palakkad and Wayanad can also be perceived. The cropping pattern in Kerala has been changed following the climatic changes in favour of commercial crops, which are more resistant to thermal and other climate-induced stress when commercial crops like coconut and cotton are dominant in Palakkad. In contrast, in Wayanad, plantation crops are dominant commercial crops grown.

Performance of paddy cultivation concerning Kerala state and comparative analysis of the same with Palakkad and Wayanad shows paddy cultivation is undergoing a critical challenge. Paddy cultivation faces severe competition from the other cash crops like rubber, coconut, and banana. On the one hand, the area under paddy and production is decreased for the period under study; however, the productivity of paddy could be maintained due to intensive cultivation of paddy. The state's declining paddy production will have adverse economic, social, and ecological implications for the Kerala economy. Production and productivity of paddy cultivation are subjected to greater variability in its growth pattern for the Kerala state as a whole on account of climate change. Farmers need to adapt and cope with climate change to maintain production and productivity sustainably. Therefore, the task of the next chapter is to understand how far the performance of farmers in terms of their efficiency is influenced when farmers are adapting and coping with climate change from micro-level primary data.

CHAPTER 4

THE CHANGING CONTEXT OF PADDY CULTIVATION IN KERALA

4.1. Introduction

The agriculture sector in Kerala occupies a significant role in the Kerala economy. According to the Kerala State Economic Review for 2021, the agriculture economy faces challenges on account of decelerating growth, risks from climatic uncertainties and variabilities, variations in commodity prices, and marketing of agricultural produce. Paddy cultivation in Kerala, in particular, is confronted with long-term policy, technological, and environmental issues (Thomas, 2011). The status of paddy cultivation in Kerala, Wayanad and Palakkad has already been covered in the previous chapter. The present chapter attempts to understand the changing context of paddy cultivation in Kerala, Wayanad and Palakkad, under three sections. The first section discusses socioeconomic and demographic changes in paddy cultivation in the study area. The technological changes in the paddy cultivation in the study area is handled in the second section. Last section discusses climate change impact on paddy cultivation in the study area.

Table: 4.1 Demographic Details in Kerala, Wayanad and Palakkad in 2011

Population Structure	Kerala	Palakkad	Kuzhalmandam	Alathur	Wayanad	Panamaram
Total Population	33406061	2809934	1,74,611	2,68,098	817420	45,627
Male	16027412	1359478	84,665	1,30,550	401684	22668
Female	17378649	1450456	89,946	1,37,548	415736	22959
Rural	17471135	2133124	1,74,611	2,41,378	785840	45627
Urban	15934926	676810	0	26,720	31580	0
No of Households	7835517	636211	40,665	62172	190263	10334
density	860	627	881	644	384	214
sex ratio	1084	1067	1062	1052	1035	1212
literacy	94	89.31	78	78.4	89.03	35573
SC	9.1	14.37	41,783	36,122	3.89	1026
ST	1.45	1.74	144	1267	18.53	10815
No of Village	1018	156	7	9	48	5
No of Towns	520	21	0	0	1	0

Source: District Census Report,2011

Table: 4.2 Demographic Details in Kerala, Wayanad and Palakkad in 2001

Population Structure	Kerala	Palakkad	Kuzhalmandam	Alathur	Wayanad	Panamaram
Total Population	31841374	2617482	166029	253385	780619	178751
Male	15468614	1266985	80391	123172	391273	NA
Female	16372760	1350497	85638	130213	389346	NA
Rural	23574449	2260907	166029	253385	751007	NA
Urban	8266925	356575	0	0	29612	NA
No of Households	6707811	529016	34846	58397	166136	NA
density	819	584	864	777	366	337
sex ratio	1058	1066	968	1057	995	NA
literacy	90.86	84.35	80.5	82.6	85.25	NA
SC	3123941	432578 (16.52)	13828	43791	3123941	NA
ST	364189	39665	140	89	364189	NA
No of Village	1364	144	14	19	48	NA
No of Towns	60	4	0	0	1	NA

Source: District Census Report, 2001,

4.2 Collective Paddy Farming by Padashekhara Samithies.

The State government launched an initiative known as Padashekhara samithi for paddy production in the late 1980s. Padashekhara samithi is the cooperative of the paddy farmers locality registered to promote cultivation of paddy and allied crop. These collectives of paddy farmers are an institution that arose as a result of cooperative farming efforts. It organises farmers in rice-growing villages, and the members democratically elect their leaders. Padasekkara Samithis and Krishi Bhavans[17]play a crucial part in the revival of rice farming in Kerala. Through Padasekhara Samithis, Krishi Bhavans provide farmers with subsidised seeds

Table: 4.3 Padshekhara samithies in the Study Area.

Community Development Block Kuzhalmandam			
Gram Panchayath	No Padashekhara Samithies	No of Farmers	Area(Ha)
Kuzhalmandam	44	2236	1187.95
Peringottukurrish	28	2129	1803.8
Kuthannur	25	2137	880.39
Kannadi	28	1695	853.08
Koyttayi	33	1899	660.951
Mathure	34	2005	925.49
Thenkurissi	26	1737	904.09

[17]Agriculture support institutions run by the state's Agriculture Department and operated by panchayats

Community Development Block Alathur			
Gram Panchayath	No of Padashekhara Samithies	No of Farmers	Area(Ha)
Alathur	17	1202	483.89
Puthukkode	10	886	326.52
Kannambra	13	1206	425
Kavassery	19	1782	718.64
Erimayur	27	2483	1180.81
Kizhakkanchery	24	1558	519.3
Tharur	22	1486	576.97
Vadakanchery	22	1256	46
Community Development Block Panamaram			
Gram Panchayath	No of Padashekhara Samithies	No of Farmers	Area(Ha)
Panamaram	40	1800	890
Kaniyambetta	15	759	508
Poothadi	21	1275	450
Pulpally	10	971	357.4
Mullamkolly	16	371	140

Source: Field Survey

and fertilisers. Samithies were also entrusted with the responsibility and management of machinery like harvesters, threshers, crushers, and tractors acquired with panchayath funds and made available to paddy farmers. The State's financial aid for ensuring food security for paddy cultivators is channeled through Samithies.

Padashekhara Smithies' establishment in the State can also be viewed as an important institutional change in paddy cultivation to adjust with the climate change issues. It has been observed in the study area that adaptation and coping practices to climate change, such as applying for crop insurance, selecting specific improved seed varieties, decision to go for delaying in sowing, and switching between direct sowing and transplanting methods of cultivation, are only possible through farmers' membership in group farming, such as Samithies. The majority of members in the Samithi of Wayanad and Palakkad, for example, have chosen the Valichoori or Uma[18] seed varieties of paddy. If a member does not choose Uma; an early maturing seed variety preferred by the majority of Samithi members, the farmer has to face the brunt of consequences, such as production loss owing to pest and pathogen outbreaks, late maturing, and harvesting. To some extent, the introduction of collective farming

[18] Uma and Valichoori have maturity periods of 120 and 140 days, respectively, and are improved seed varieties of paddy discovered by the regional research station to respond to early and late arrival of rainfall.

in paddy cultivation was also able to address technological constraints by disseminating information among farmers about the timing of water availability through canal irrigation, seed and fertiliser availability with Krishi bhavan, availability of machinery for various farm operations, and early climate warning.

4.3 Leased Cultivation of Paddy by Joint Liability Group

Another important changing background of paddy cultivation in the study area may be women's collective farming of paddy on lease land under the Kudumbashree initiative[19]. In Kerala 's 2014 Action Plan on Climate Change, collective farming through Kudumbashree was highlighted as a key programme in the agriculture sector relevant in the context of climate change. Over a long period, a growing number of small, medium, and large parcels of cultivable land were left fallow in the State (Abraham, 2019), due to labour shortages, high costs of cultivation, commercial crops' export prospects, growth in the number of absentee landowners, and low profitability (Thomas, 1996). In 2008, the Kerala Government passed the "Kerala Conservation of Paddy Land and Wetland Act", which prevented rice fields from being left fallow or used for other purposes without authorisation from a district/state level monitoring committee. One of the main implications of the act is the resurgence of paddy farming through Joint Liability Groups (JLG), where landless women operating under the Kudubashree banner across the State have exhibited an increased presence in leased paddy cultivation.

Table: 4.4 Leased in Area of Paddy in the Study Area

	Palakkad		**Wayanad**	
	Area (Acere)	No of Farmers	Area (Acere)	No of Farmers
Leased in cultivation	29.07	19(9.9)	230.78	57(41.3)
Owned Cultivation	288.10	173(90.1)	389.82	81((58.7)
Total	317.17	192(100)	620.6	138(100)

Source: Field Survey, 2021

Kudumbashree helps to stay landless women in agriculture by providing food security and improving the livelihoods in Kerala through JLG collective farming in paddy. Paddy (27 per cent of area) is the main crop cultivated by the Kudumbashree group during the 2009-10 lease land farming season, followed by plantation and vegetables (KSAPCC, 2014). The reduced area under fallow and other cultivable wastelands (Table 3.2) observed in the previous chapter

[19] Collective farming by State Poverty Eradication Mission through Kudumbashree is known as Harithashree.

at the state level could be attributed to the advent of Kudumbashree supported paddy cultivation through JLGs. In 2016, the Joint Liability Group (JLG) of the Kudumbashree program cultivated paddy on 13,300 hectares in Kerala, with Palakkad cultivating 2343 ha (17.6 per cent) and Wayanad cultivating 327 ha (2.5 per cent) (Kudumashree, 2017). However, it was discovered in the field survey (Table 4.4) that the majority of paddy farmers, 41.3 per cent of those in the Wayanad study as compared to Palakkad (9.9 per cent), were engaged in leased paddy cultivation.

4.4 Labour Shortage

Demographic changes in work participation, with reference to agricultural labourers and cultivators, have been seen in the study area, in line with the changing background of Kerala state's demography during the last two decades. Land use pattern changes and cropping pattern changes (Viswanathan 2016), the emergence of the MGNREG program (Prakash, 2007) and gulf migration (Zachariah, 2005) have resulted in acute labour shortage and higher wages. It can be inferred from the table that agriculture work participation, mainly among cultivators and agriculture labours, is fast changing in Kerala, Wayanad and Palakkad between 2001 and 2011. The decline of cultivators and agriculture labour will seriously affect paddy cultivation.

Figure: 4.1 Category of Workers in Kerala, Palakkad & Wayanad

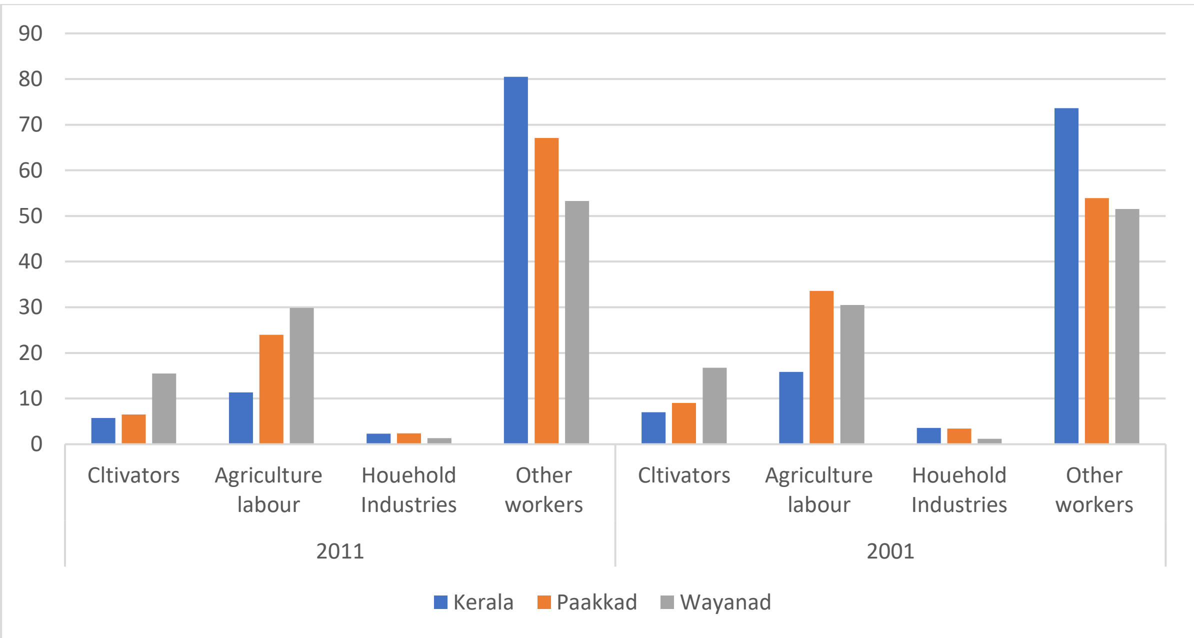
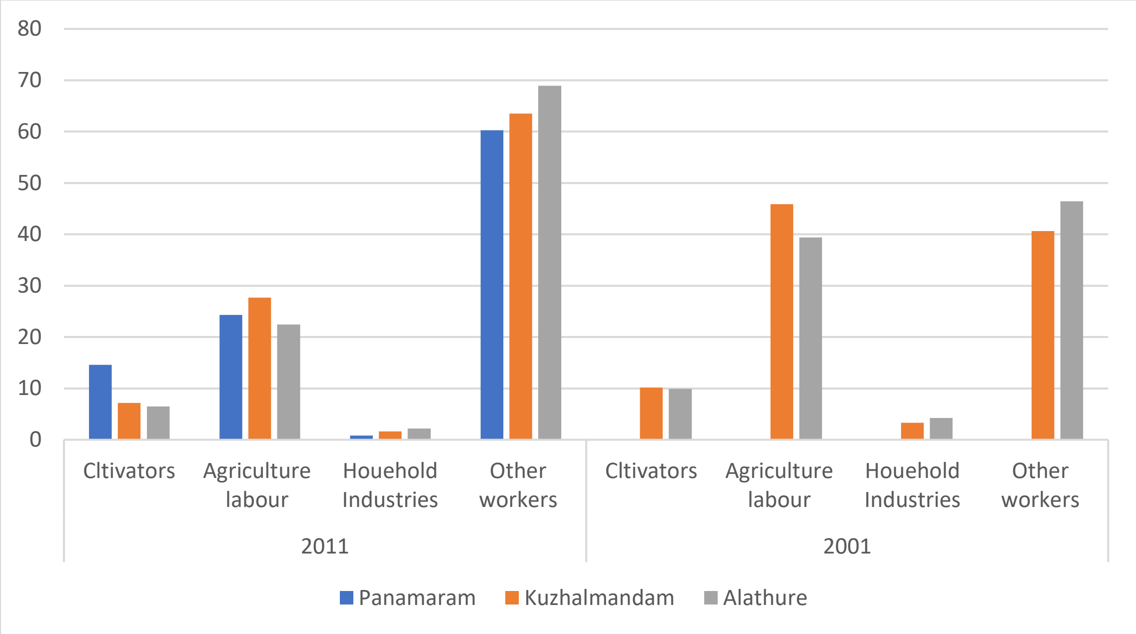


Table: 4.5 Category of Workers

	Variable	Kerala	Palakkad	Kuzhalmandam	Alathur	Wayanad	Panamaram
2011	Population variable	33406061 (2.76)	2809934 (8.41)	1,74,611 (6.21)	2,68,098 (9.54)	817420 (2.45)	45,627 (5.58)
	Main workers	9329747 (27.93)	875540 (31.16)	62,665 (35.89)	93,303 (34.80	263445 (32.23)	14,414 (31.59)
	Marginal workers	2289316 (6.85)	166800 (5.94)	5,317 (3.05)	15,853 (5.91)	76632 (9.37)	4317 (9.46)
	Total workers	11619063 (34.78)	1042340 (37.09)	73,891 (42.32)	1,09,156 (40.71)	340077 (41.60)	18,731 (41.05)
	Cultivators	670253 (5.77)	67,805 (6.50)	5,317 (7.20)	7,051 (6.46)	52759 (15.51)	2,732 (14.59)
	Agriculture labour	1322850 (11.39)	249949 (23.98)	20,436 (27.66)	24,469 (22.42)	101630 (29.88)	4,558 (24.33)
	Household Industries	273022 (2.35)	25035 (2.40)	1,206 (1.63)	2,384 (2.18)	4574 (1.34)	148 (0.79)
	Other workers	9352938 (80.50)	699551 (67.11)	46932 (63.51)	75252 (68.94)	181114 (53.27)	11293 (60.29)
2001	Population variable	31841374 (30.10)	2617428 (8.22)	1,66,029 (6.34)	253385 (8.49)	780619 (2.45)	**
	Main workers	8236973 (25.87)	768620 (29.37)	55,086 (33.18)	82530 (32.57)	219789 (28.16)	-
	Marginal workers	2046914 (6.43)	176432 (6.74)	15,776 (9.50)	18020 (7.11)	88824 (11.38)	-
	Total workers	10283887 (32.30)	945052 (36.11)	70,862 (42.68)	100550 (39.68)	308613 (39.53)	-
	Cultivators	724155 (7.04)	85638 (9.06)	7,205 (10.17)	9997 (9.94)	51751 (16.77)	-
	Agriculture labour	1620851 (15.85)	317192 (33.56)	32,506 (45.87)	39607 (39.39)	94139 (30.50)	-
	Household industries	369667 (3.59)	32832 (3.47)	2,341 (3.30)	4257 (4.23)	3600 (1.17)	-
	Other workers	7569214 (73.60)	509390 (53.91)	28,810 (40.66)	46689 (46.43)	159123 (51.56)	-

Source: District Census HandBook Wayanad 2001, 2011, District Census HandBook Palakkad 2001, 2011, Note: Values in the paranthesis for main workers and marginal workers expresess per cent to total population of India, Kerala, Palakkad and Wayanad. Values in the bracket for other category of workers expressed in per cent to total workers ** Data related to the variable for Panamaram block became available after 2011 census onwards as Panamaram Community Development Block formed in 2010 after the amalgamation of gram panchayats Pulpally, Mullankolly, Puthadi, Panamarm, and Kaniyambetta Gram Panchayath from Kalpetta, Mananthawady and SulthanBathery blocks

Figure: 4.2 Category of Workers in Kuzhalmandam, Alathur & Panamaram



The seasonal shortage of agricultural labour is widely acknowledged as a serious difficulty facing rice farming in Kerala today. Kerala has been moving its workforce away from agriculture and into various non-agricultural occupations at a significantly higher rate than the rest of India. According to the National Sample Survey (NSS), only 35.5 per cent of Kerala's workforce was employed in agriculture, fishery, or forestry in 2004–05, compared to 56.5 per cent in India. In recent years, Kerala's occupational diversification has been helped by the massive spread of mass education and the rapid development of construction and service-sector incomes (Thomas, 2011).

Table: 4.6 Reasons for Labour Shortage.

Reasons for labour Shortages	No of Famers perceived in Palakkad (%)	No of Famers perceived in Wayanad (%)
The availability of other local jobs with higher wage	75	81
The emergence of MGNREGA	63	71
Seasonal nature of agriculture jobs	42	57
The transition to a full-time job	36	50
Perception of agriculture occupation as low esteem	27	31
Migration to other cities	10	19
Higher educational attainment and occupational mobility,	7	14
International migration	2	6

Source: Field Survey, 2021

Labour shortages are widely seen in the study area as well. Labour market dynamics as such have had significant repercussions on paddy production in the study area. The paddy farmers from both study areas believed the labour scarcity was caused by the availability of alternative local jobs with higher wages. When workers in non-farm occupations earn between Rs 1000 and 1100 per day, both male and female agricultural labourers are paid a barely sufficient wage for their subsistence. For instance, male agriculture labour wages range between Rs 550 and 750 per day in the Wayanad–Palakkad paddy growing area, while female agricultural workers earn between Rs 450 and 650 per day (Field Survey, 2021). The availability of other local jobs with a higher wage, the emergence of MGNREG, seasonal nature of agriculture jobs, shifting to permanent occupation, perception of agriculture occupation as low esteem, higher educational attainment and occupational mobility, migration to other cities and the foreign countries are some of the other perceived reasons for labour shortages in the study area.

4.5 Changes in the Cropping and Commercialisation

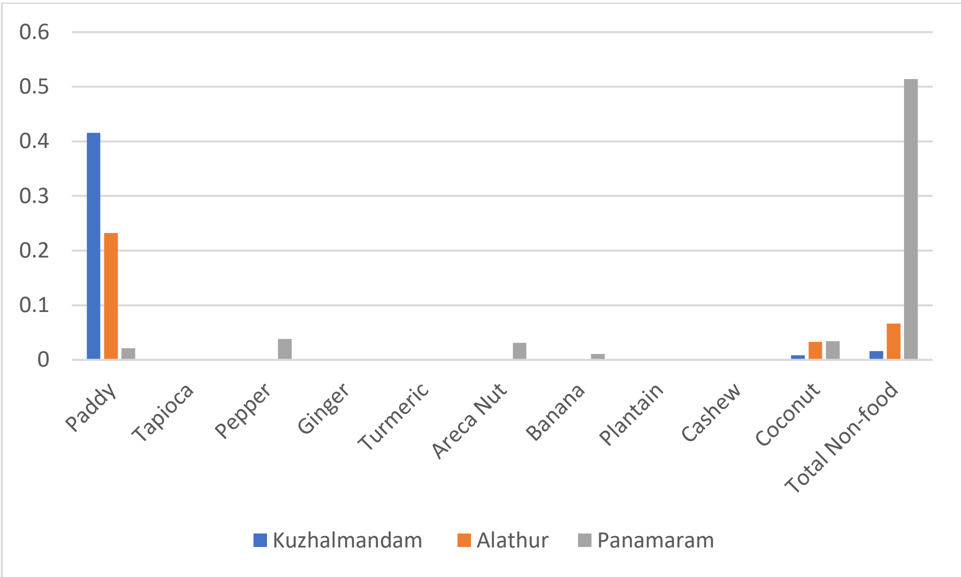
The transition from food crops to non-food crops has been the most noticeable change in Kerala's cropping pattern from 1954-55 to 2016-17 (Johnson D, 2018). During this time, there was a shift away from rice farming and toward more lucrative crops like coconut, arecunut, banana, tea, coffee, and rubber. Between the 1970s and 1996, rice had the “smallest increase in average farm prices among key agricultural commodities in Kerala” (George et al 2001). Changes in land use and cropping patterns away from paddy-based food crops have a negative impact on food security and the environment in the State (Rejula, 2015). Although, price volatility especially among cash crops grew as a result of the adoption of new multilateral trade agreements during 1990s, and given the limited capacity of the state government to protect cultivating farmers due to quantitative limits (Joseph 2005, Johnson D, 2018).

The present study attempted to measure extent of commercialisation in the Palakkad and Wayanad study area using Herfindahl Index (HI) as specified in the following formula.

$$\mathbf{HI} = \sum_{i=1}^{n} \mathbf{P}i^2$$

The HI is the measure of concentration, where index is calculated by taking the sum of area proportion of each crop in the total cropped area . In the formula, n is the total number of crops, P*i* represent acreage proportion of i^{th} crop in the total cropped area. With the increase in diversification, the index value decrease , HI take the value of one when there is complete specilisation and tends to zero when N become large.

Figure: 4.3 Crop Diversification in Palakkad and Wayanad



Note: values in the y axis is HI

Available block-level data since 2009 for the study area, for the area under important food crops like paddy and tapioca as well as non-food crops like pepper, ginger, turmeric, areca nut, banana, plantain, cashew, and coconut, were used to calculate the index.

Table: 4.7 Crop Diversification in Palakkad, Wayanad and Panamaram

Crops	Kuzhalmandam	Alathur	Panamaram
Paddy	0.41581	0.23238	0.02111
Tapioca	0.00002	0.00026	0.00066
Pepper	0.00001	0.00018	0.03796
Ginger	0.00003	0.00001	0.00118
Turmeric	0.00003	0.00003	0.00001
Areca Nut	0.00001	0.00025	0.03139
Banana	0.00012	0.00013	0.01087
Plantain	0.00006	0.00045	0.00026
Cashew	0.00002	0.00004	0.00001
Coconut	0.0083	0.03297	0.03422
Total Non-food	0.01603	0.06667	0.51425

Source: Agriculture Statistics, DES, Govt. of Kerala, note: Values are calculated HI

Climate change impact may have an impact on cropping pattern changes (Duku, 2018). Crop diversification reduces risks involved in crop production due to climatic variability, whereas commercialization assists farmers in reducing high costs of cultivation and high labour shortage in paddy cultivation. However, crop diversification as an adaptation to climate change requires changing crop mix which is climate resilient which is lacking in the study area. It has been observed in the study area that although a majority of the farmers of Wayanad and Palakkad adapted to commercial crops or other tree crops, a smaller number of farmers are found adapt to resilient climate practices such as altering cropping patterns toward less water required crops.

Table:4.8 Adaptation to Climate Change by the Paddy Farmers.

Adaptation Practices	No of Farmers in Wayanad	%	No of Farmers in Palakkad	%
Change in Cropping Pattern towards commercial crops	84	43.8	127	66.1
Mixed farming	79	41.1	51	26.6
Altering cropping patterns to less water-intensive or rained crops	59	30.7	69	35.9
Increase in the number of livestock	67	34.9	46	24
Shifting from crops to trees crops	73	38	30	15.6

Source: Field Survey, 2021.

Changes in cropping patterns towards commercial crops and crop diversification in the study area may also be attributed to farmers' adaptation to climate change. This could explain why paddy fields in Wayanad and Palakkad are increasingly being used to grow other crops such as coconut, arecunut, pepper, and banana crops. Although, farmers switching to the cropping pattern towards perennial and thermal resistant crops like coconut and arecunut help to better adapt with climate change in the study area, however crop switching results in the large-scale filling of paddy fields and hill levelling, on the other hand, has had an impact on the environment of the Wayanad in particular. As a result, there is more drinking water scarcity throughout the summer, as well as declining water tables, land erosion, and climate change (District HDI Report, 2010). Farmers are increasingly shifting away from wet rice fields and toward drier, permanent crops such as coconut, areca nut, and rubber as a result of growing apathy toward paddy farming.

Table: 4.9 Cropping Pattern Changes in the Study Area

Blocks	Crops	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Kuzhalmandam	**Paddy**	5.33	5.35	5.45	5.15	5.57	5.66	5.46	5.37	4.76	5.49	5.51	5.38
	Tapioca	0.11	0.07	0.08	0.08	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
	Areca Nut	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.03
	Banana	0.019	0.021	0.012	0.025	0.02	0.009	0.013	0.012	0.009	0.01	0.004	0.004
	Coconut	0.73	0.72	0.83	0.82	0.77	0.78	0.75	0.81	0.7	0.71	0.72	0.76
	Non food	1.09	1.05	1.22	1.27	1.04	1.01	1.03	1.1	0.97	0.96	0.93	0.99
Alathur	**Paddy**	4.31	4.45	4.3	3.65	4.02	3.79	4.02	3.71	3.47	3.91	4.21	4.36
	Tapioca	0.17	0.18	0.18	0.17	0.16	0.14	0.17	0.11	0.1	0.1	0.07	0.06
	Areca Nut	0.11	0.34	0.17	0.14	0.13	0.12	0.07	0.1	0.1	0.11	0.09	0.09
	Banana	0.16	0.18	0.16	0.1	0.09	0.07	0.07	0.08	0.06	0.09	0.04	0.05
	Coconut	1.58	1.71	1.76	1.54	1.62	1.43	1.42	1.46	1.43	1.4	1.41	1.39
	Non food	2.41	2.9	2.63	2.22	2.25	1.98	1.9	1.99	1.92	1.94	1.87	1.82
Panamaram	**Paddy**	-	-	-	1.62	1.72	2.4	1.55	1.5	1.35	1.56	1.48	1.35
	Tapioca	-	-	-	0.43	0.4	0.24	0.33	0.27	0.24	0.26	0.21	0.2
	Areca Nut	-	-	-	1.67	1.84	2.04	1.89	2.39	1.97	1.99	2	1.92
	Banana	-	-	-	1.32	1.09	2.05	1.1	0.99	0.95	1	0.81	1.12
	Coconut	-	-	-	1.97	1.96	1.89	1.93	2.84	2.08	1.99	2.03	1.79
	Non food	-	-	-	7.37	7.28	8.61	7.76	10.02	7.98	8.05	7.44	7.21

Source: Agriculture statistics, Directorate of Economics and Statistics, Govt of Kerala, Values expressed in percent to the district total cropped area

4.6 Technological Changes in Paddy Cultivation in Study Area

According to a study (Anja et al., 2014) published in “A handbook of trans disciplinary approaches to agrobiodiversity”, the Wayanad region has transitioned from an agrarian economy based on staple food production to one based on cash crops and plantations. Now, coffee, tea, pepper, cardamom, and rubber are important plantation crops cultivated in Wayanad. In case of paddy cultivation, While Kerala has three rice seasons, Wayanad follows two paddy seasons known as Nanja and Punja[20]; however the majority of the paddy farmers cultivate and harvest paddy only in the Nanja season. The majority of the rice fields remained as fallow during the autunm season and punja season due to inadequate irrigation facilities. There is no autumn paddy cultivation in the district.

Palakkad district “is known as the rice bowl of Kerala”. Palakkad follow three paddy seasons, known as Virippu, Mundakan and Puncha[21] . The Palakkad district has 27.8 % area under paddy cultivation to the gross cropped area of the state and 42.3 % share in rice production in the state rice production. In Palakkad, there have not been any appreciable improvements in the area under paddy cultivation after reaching its highest level to 34.6 % in 2005-06. According to surveys, in the last four decades, the district has lost 1,03,980 hectares of rice fields. However, Paddy production in Palakkad registered an increase from 29.9 % in 1990-91 to 42.3 in 2019-20. District uses a significant portion of cultivable land for rising food crops. It accounts for 80 % of the gross cropped area. Coconut, groundnut, sugarcane, pepper, banana are the other important crops grown. In addition, orange, coffee, cardamom, mango and vegetables are cultivated in Nelliyambathy in 325 ha. Even though paddy acreage increase is low, higher production and intensive paddy cultivation have played a part in the higher productivity in Palakkad. Productivity of the Palakkad increased from 2230 kg/ha in 1990-91 to 2648 kg/ha in 2011-12 and further to the all-time high at 3224 kg /ha in 2019-20.

[20] Paddy seasons of Wayanad known in local name as Nanja and Punja. Nanja paddy season occure in winter starts in September-October and harvest in December-January, where asPunja is summer paddy season begin in December-January and ends in March-April.

[21] As per agriculture climate, Kerala has three paddy season known in local name as Virippu, Mundakan and Puncha. Virippu (Autumn-paddy) is the first crop season occure in April-May and harvest in September-October. Mundakan(Winter paddy) is the second crop season starts in September-October and end in December-January. Puncha (Summer paddy) is the third crop season starts in Decemcer-January and harvest in March-April.

Table: 4.10 Area and Production of Paddy in Study Area

Year	Area and Production of Paddy			
	Palakkad		Wayanad	
	Area	Production	Area	Production
1990-91	26.0	29.9	3.6	3.9
1995-96	28.8	29.4	4.3	4.9
2000-01	34.2	34.9	4.3	4.5
2005-06	34.6	42.3	4.2	4.5
2015-16	27.6	41.6	4.7	4.3
2019-20	27.8	42.3	3.7	3.3

Source: Agriculture Statistics, Eco Stat, DES, Govt. of Kerala. Note: Values indicate proportions to the state gross cropped area and total state production of paddy

Table: 4.11 Productivity of Paddy in Study Area (Yield in kgs /ha)

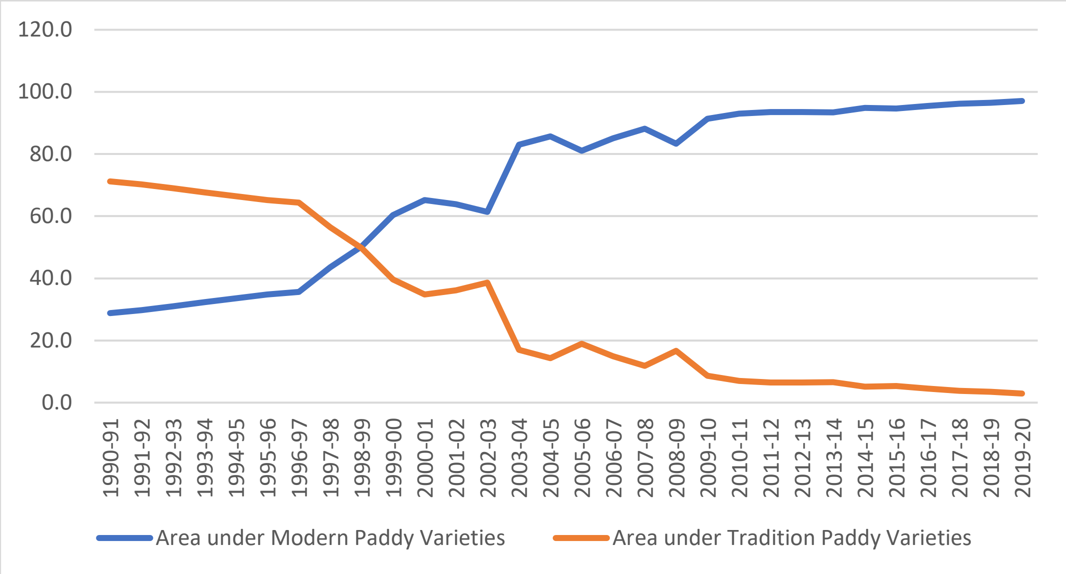
Year	Palakkad	Wayanad	Year	Palakkad	Wayanad
1990-91	2230	2063	**2005-06**	2341	2468
1991-92	2344	2186	**2006-07**	2473	2597
1992-93	2297	2382	**2007-08**	2463	2585
1993-94	2337	2225	**2008-09**	2499	2657
1994-95	2240	2124	**2009-10**	2648	2552
1995-96	2067	2288	**2010-11**	2493	2525
1996-97	2291	2199	**2011-12**	2672	2615
1997-98	2173	2217	**2012-13**	2389	2742
1998-99	2213	2218	**2013-14**	2872	2679
1999-00	2287	2587	**2014-15**	2851	2701
2000-01	2209	2253	**2015-16**	2816	2575
2001-02	2323	2495	**2016-17**	2202	2640
2002-03	2104	2412	**2017-18**	2634	2715
2003-04	1802	2303	**2018-19**	2792	2878
2004-05	2343	2578	**2019-20**	3224	2663

Source: Agriculture Statistics, Eco Stat, DES, Govt. of Kerala. Note: Values indicate kilogram per hectare

4.7 Area Covered under Traditional and Modern Varieties.

When new agricultural technology, popularly known as the New Agriculture Strategy (NAS), was introduced in India in the 1960s, the extent of technology adoption in southern states in particular was relatively low. In Kerala, the adoption of (HYV) began only in 1968-69, and was mostly limited to rice. In Kerala, high yielding varieties accounted for 28.8% of the total paddy area, while traditional paddy varieties accounted for 71.2 percent of the total paddy area in 1990-91. Over a 30-year period, the area under modern verities increased significantly to 97.1 percent, while the area under modern verities decreased dramatically to 2.9 percent of the total area under paddy in 1990-91in the state.

Figure: 4.4 Area under Modern and Traditional Paddy Varieties in Kerala



With declining paddy area and production, intensive cultivation with high yielding varieties of seeds could maintain higher paddy productivity in the state. The expansion of area under high yielding seed varieties in the future depends on how far new seed verities are able to address climatic stress in the future. Similar to the state pattern, area expansion of new paddy seed varieties in Wayanad and Palakkad follow the same trends. Wayanad district is famous for its traditional rice verities. Wayanad used to cultivate almost 105 indigenous rice varieties by the farming community just a few decades ago, it has, however, been reduced to 20 throughout the years (MSSRF, 2018). The few surviving traditional rice varieties in Wayanad are "Adukkan, Veliyan, Chenellu, Chomala, Chenthadi, Thondi, Gandhakasala, Jeerakasala Mullankaima, and Kalladiaryan". Wayanad has experienced an apparent reversal in the changes in paddy productivity since 2004-05, and at present, Wayanad has 3.7 % and 3.3 % state's area and production of paddy. The productivity of paddy in Wayanad stood at 2663 kg/ha in 2019-20. The inability of the traditional verities to withstand harsh climate[22] coupled with low

[22] Traditional rice verities are exposed to grains falling down and bending due to the higher length of grass stand.

profitability perhaps forces farmers to shift towards high yielding verities (Jayasree et al., 2021).

Figure: 4.5 Area under Modern and Traditional Paddy Varieties in Wayanad

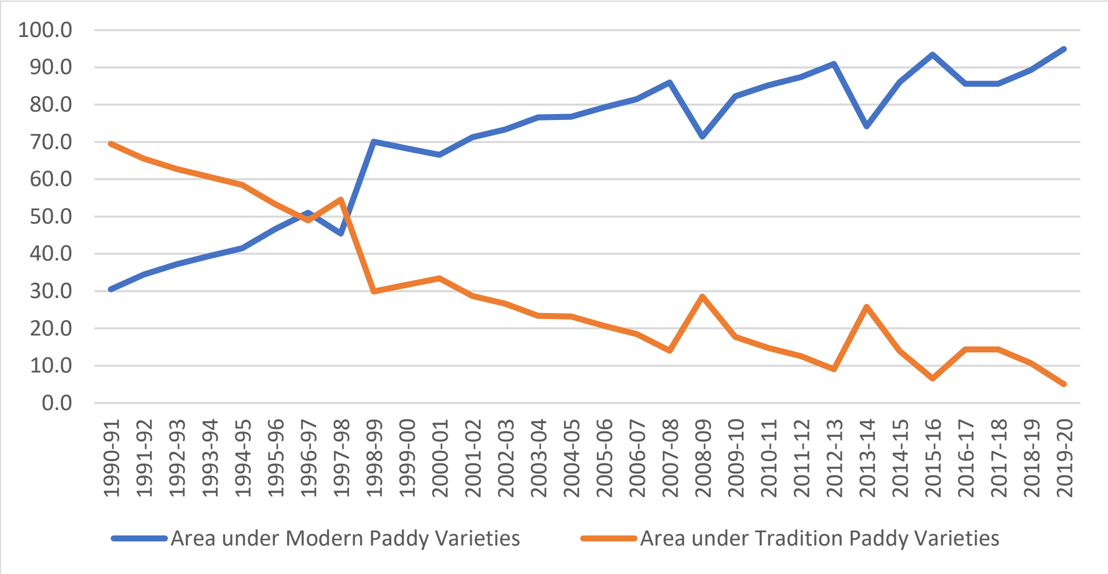
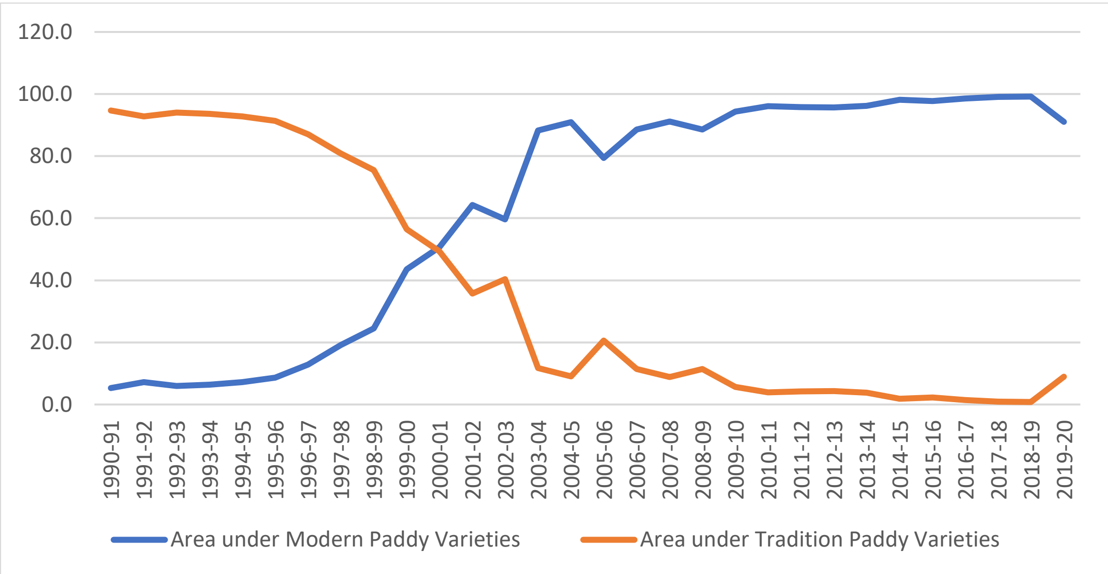


Figure: 4.6 Area under Modern and Traditional Paddy Varieties Palakkad



It has been observed from the field that still few farmers cultivate traditional seeds verities along with modern verities. It can be inferred from the table 4.12, the status of technological adoption in the study area. It was found in the study area that the majority of paddy farmers from Wayanad and Palakkad switched to new high yielding paddy seed varieties. More than 95 per cent of the paddy cultivation area is found to have been converted to high yielding seed varieties, with only 4.8 percent of the area covered by traditional seed varieties. Paddy farmers' favourite high-yielding paddy seeds include Uma, Jaya, Athira, Valichoori, Palakkadan Matta, Cherumatta, Masoori, 1000 kana, Rosematta, Vyshakh, IR 20, Navara, Sigappi, AST, Jyothi, and Kanjana. Although high yielding is the most common reason given by 90% of paddy farmers for choosing these varieties in the field, 78 percent of farmers choose high yielding paddy seeds for cultivation due to group farming. Farmers who adopt specific seed varieties

Table: 4.12 Extend of Traditional and Modern Varieties in the Study area.

Paddy Seeds	Wayanad Area	No of Farmers	Palakkad Area	No of Farmers	Total no farmers	Total area
Traditional	5.2 (1.67)	10 (7.2)	3.49 (0.61)	6 (3.2)	16 (4.8)	8.69 (0.98)
Modern	309.65(98.32)	128(92.8)	569.144(99.39)	186(96.8)	314(95.2)	878.794(99.02)
Total	314.85 (100)	138 (100)	572.634 (100)	192 (100)	330 (100)	887.484 (100)

Source: Field Survey. Note: Area is in acers, and values in the parenthesis is expressed as per cent.

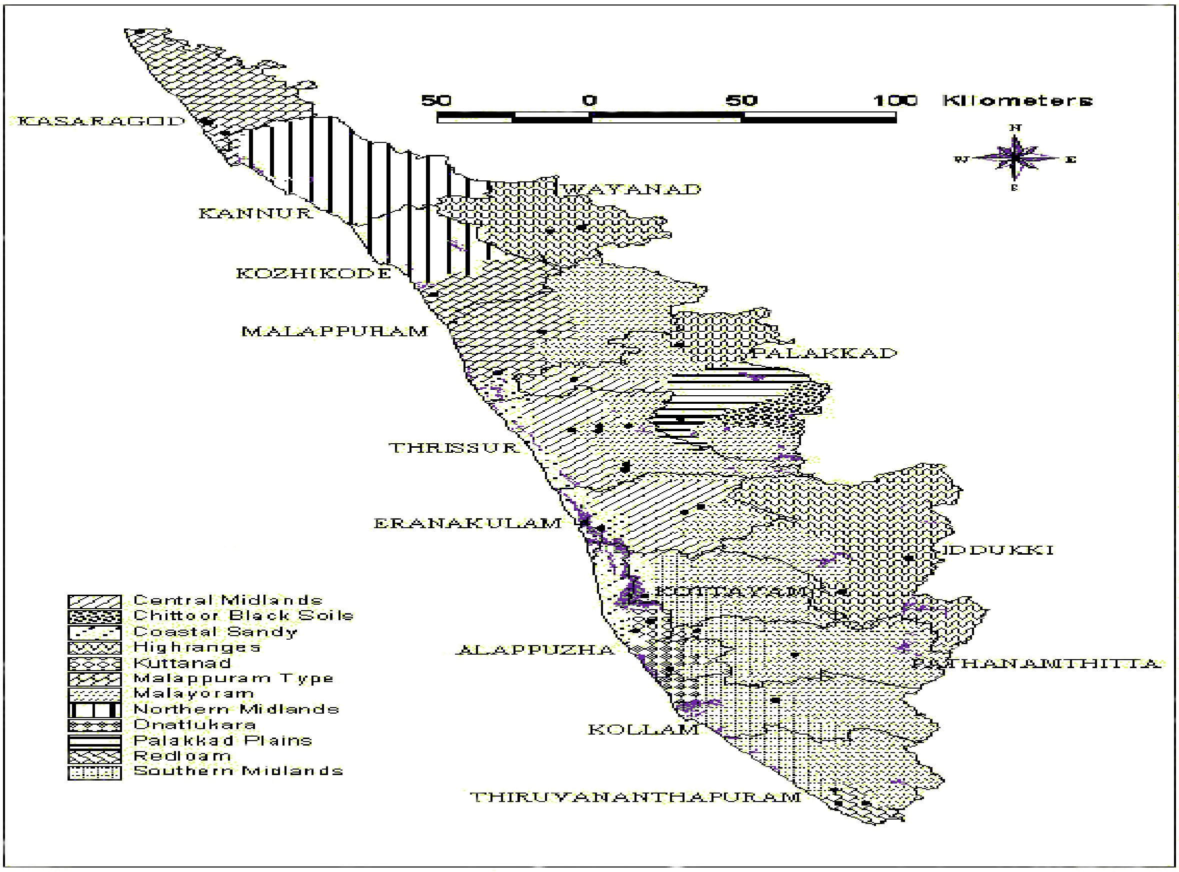
through group farming in paddy cultivation are able to overcome a variety of challenges, including pest and pathogen outbreaks, labour shortages, and machine shortages, beside the attainement of higher paddy productivity. Traditional seed varieties are more popular only among more experienced paddy farmers because they believe they can better withstand adverse weather conditions than modern varieties. Few farmers cultivate traditional seed varieties solely for their own consumption, while many cultivate modern varieties solely for the purpose of marketing.

4.8 Impact of Climate Change on Paddy Cultivation

Kerala is situated on India's southernmost tip, “bordering the Arabian Sea on the west and the Western Ghat on the east”. Kerala state has a land area of 38,863 Sq.Km, accounting for 1.18 percent of India's total land area. Kerala is divided into four geographical regions. 1. Kerala's North 2. Kerala's Central Region, 3. Kerala's South Region, and 4. Kerala's High Altitude. “The state has a total of 13 Agro Climatic Zones viz., Onaattukara, Coastal Sandy, Southern Midlands, Central Midlands, Northern Midlands, Malappuram type, Malayoram, Palakkad plains, Red loam, Chittoor black soil, Kuttanad, Riverbank alluvium, High ranges”. It can be seen from the map

The state has a relatively rich rainfall endowment, with annual precipitation of around 2600 mm. Ninety percent of this precipitation falls during the two monsoon seasons, from June to August (southwest) and October to November (east) (northeast). The southwest monsoon receives approximately 60% of the annual rainfall, while the northeast monsoon receives approximately 30%. From December to March there is very little rainfall, but the occasional rainfall during this period is a very critical requirement for cultivation as Kerala still depends upon rainfall for raising many of the crops. The spread of rainfall is relatively better with 6-7 months having rainfall above or nearly around the monthly average . The quantum of annual precipitation is concentrated around lesser periods towards the northern part of the state while it is spread over longer periods in the southern parts . The co-efficient of variation of the annual rainfall is below 20% and hence, agriculture is expected to flourish under relatively stable conditions . However, coefficient of variation of monthly rainfall is high . As a result, stability in production can be ensured only with the support of irrigation at least for most of the major crops to increase their production and productivity .

Map: 4.1 Agro Climatic Zones of Kerala



Source: Adapted from Kerala Agriculture University: 2002

Palakkad and Wayanad districts of Kerala state comes under the high ranges and malayoram zone of the Kerala agro-climatic region. Each district also represents a mid-altitude and a high-altitude district in Kerala, respectively. In various parts of Kerala, floods and droughts of varying severity have occurred on a regular basis. Climate change and disaster management report (2017) of the Kerala state says that extreme climatic conditions such as drought, flood and landslides are quite common in the malayoram and high ranges of Kerala. Since 2018, three consecutive years of flooding have disrupted the lives of people in all 14 districts of Kerala (DDMR, 2021). The temporal distribution of Natural disasters in Kerala since 1970 is given in the table 4.13. Kerala has experienced ten different drought and flood years of varying severity since 1973. However, the droughts of 1983, 1985, 1986, 1987, and 2012 were severe (Nathan 2000, DSAR, 2017), and the flood of 2018 is often referred to as the worst flood of the century.

Table: 4.13 Temporal Distribution of Natural Disaster in Kerala since 1970

Year	Nature of disaster	Year	Nature of disaster
1973	Drought	**1997**	Flood
1977	Wind storm	**1998**	Flood
1983	Drought	**2000**	Flood
1985	Drought	**2002**	Drought
1986	Drought	**2004**	Tsunami, Flood
1987	Drought	**2012**	Drought
1991	Flood	**2016**	Drought
1992	Flood	**2017**	Drought
1992	Landslide	**2018**	Flood
1994	Flood	**2019**	Flood
1996	Flood	**2020**	Flood

Source: Data compiled from various reports of the Kerala state disaster management.

4.9 Climate Variability of the Study Area

From below figure 4.7, 4.8 and table 4.14, Kerala got around 68 % of annual rainfall from South west monsoon season between 1978-2018. It is also clear that, monthly, seasonal and annual rainfall does not show any significant increasing trend. June and July monthly rainfall trends

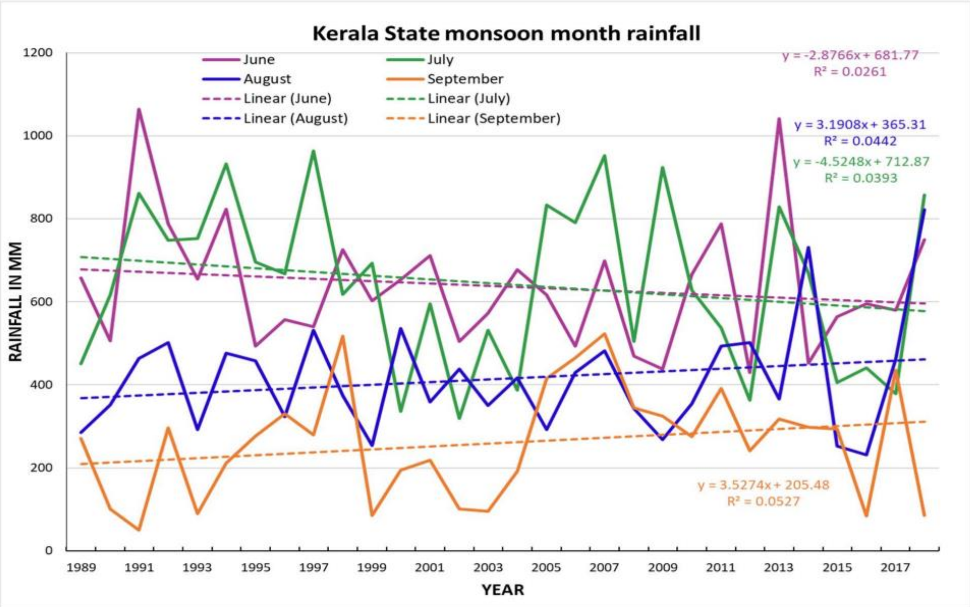
Table: 4.14 Status of Annual and South-west Monsoon Season Rainfall (mm) for 1989-2018.

	June	July	August	September	JJAS	Annual
Mean	637.2	642.7	414.8	260.2	1954.8	2855.6
CV	24.6	31.3	32.2	52.0	19.1	14.0

Source: Indian Meteorological Department, 2020

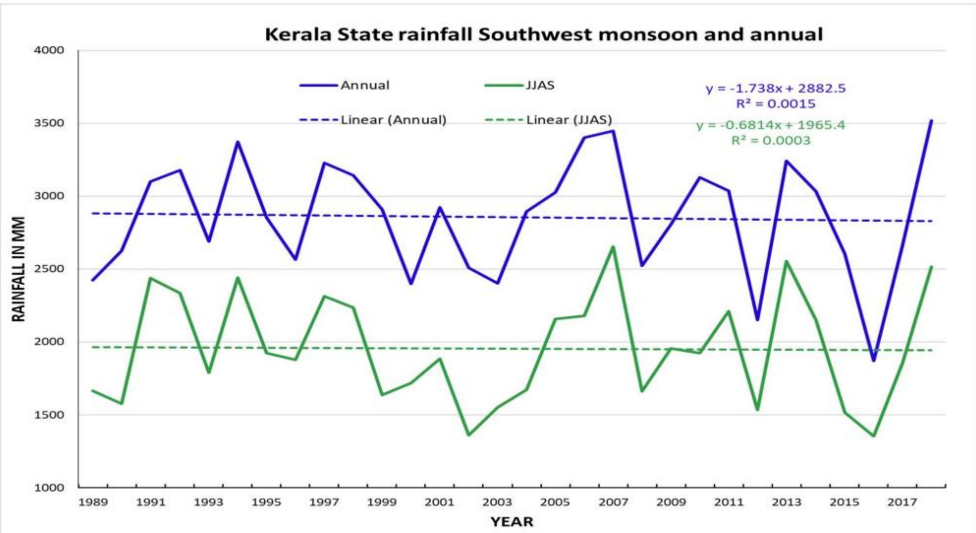
shows decreasing trend whereas August and September months rainfall shows a decreasing trend. The variability of South-west monsoon rainfall between June to September is in increasing, it poses a significant risk to the agricultural economy of the Kerala state since it is the important crop season. From the figure, it can be inferred that, monthly, seasonal and annual rainfall does not show any significant increasing trend. June and July monthly rainfall trends show decreasing trend whereas August and September monthly rainfall show decreasing trend.

Figure: 4.7 Trend in Monsoon Months Rainfall (mm) in Kerala



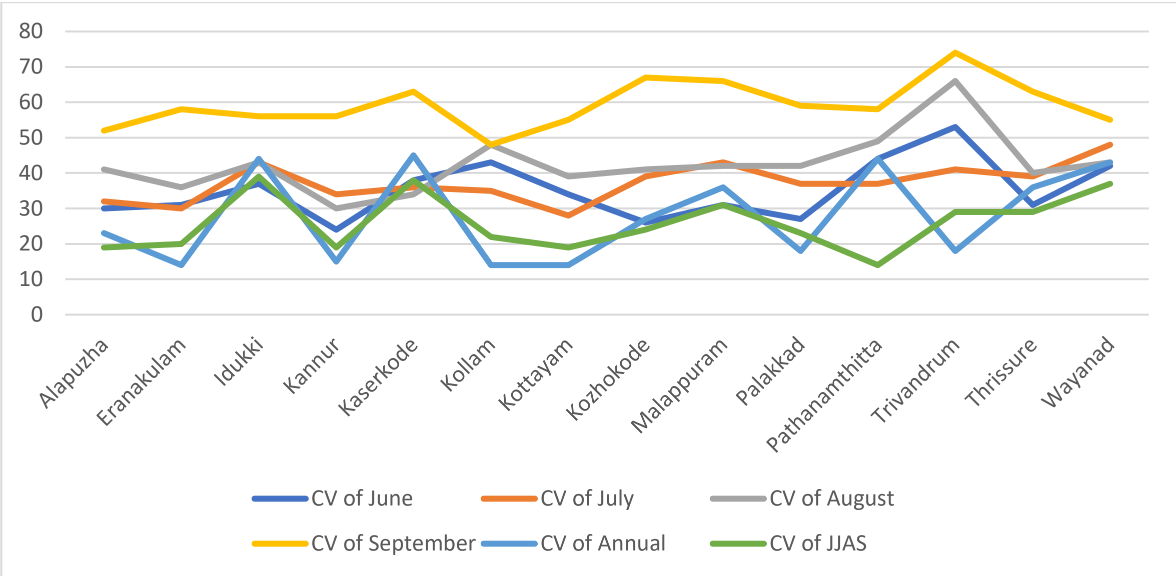
Source: Indian Meteorological Dept, 2020.

Figure: 4.8 Trend in Southwest Monsoon Rainfall(mm) in Kerala



Source: Indian Meteorological Dept, 2020.

Figure: 4.9 South West Rainfall Variability at the District Level During 1989-2018



Source: Indian Meteorological Department, Trivandrum, 2020

The figure 4.9 clearly shows that the southwest monsoon season has the greatest variability in Kasaragod, Idukki, and Pathanamthitta, while minimum variability in Kannur, Palakkad, Ernakulam, Kottayam, and Alappuzha Kollam. Kasargod, Wayanad, Idukki, and Pathanamthitta have the highest annual rainfall variability, while Kannur, Palakkad, Eranakulam, Kottayam, Kollam, and Trivandrum have the lowest. Rainfall for the month of June has the highest variability for Trivandrum and the lowest for Kannur. July month rainfall shows the highest variability for Wayanad and lowest for Kottayam. Rainfall for the month of August has the highest variability for Trivandrum and the lowest for Kannur. September month rainfall shows the highest variability for Trivandrum and the lowest for Alapuzha.

4.10 Climatic Variability in the Palakkad and Wayanad

The table 4.15 describes average rainfall, and minimum and maximum temperature statistics for the Palakkad and Wayanad. It can be inferred from the table that there is no significant variability in minimum temperature and maximum temperature for Wayanad and Palakkad between 1981-2020. However, it has been observed significant variability in monthly rainfall for the Wayanad and Palakkad. Especially rainfall variability is significantly greater for Palakkad relative to Wayanad.

Table: 4.15 Mean and Variance of Rainfall and Temperature in Wayanad and Palakkad since 1980.

Maximum Temperature in Wayanad(^{0}C)													
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	32.8	35.1	36.6	36.4	34.6	29.5	27.1	27.4	28.3	28.7	28.7	29.9	36.9
CV	2.24	2.44	2.11	2.47	2.97	3.31	0.83	0.73	0.83	0.79	0.89	2.9	0.39
Minimum Temperature in Wayanad (^{0}C)													
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	16.8	18.1	20.2	22.3	22.4	21.5	20.9	20.9	20.6	19.5	17.6	16.6	15.9
CV	1.04	0.7	0.88	0.63	0.5	0.4	0.5	0.21	0.43	1.49	2.13	1.46	6.41
Rainfall in Wayanad(mm/day)													
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	0.15	0.15	0.57	2.08	6	23.48	22.7	15.69	8.42	7.59	3.18	0.72	7.6
CV	0.05	0.06	1.39	2.51	20.57	37.87	78.31	25.69	21.59	10.13	3.96	0.38	2.22
Maximum Temperature in Palakkad(^{0}C)													
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	32.7	36.4	38.6	38.9	37.2	32.2	29.5	29.8	30.9	30.8	29.5	30.1	39.4
CV	2	1.7	1.2	1.3	2.7	4.6	1.9	1.7	2.3	2.2	1.9	3.2	0.7
Minimum Temperature in Palakkad(^{0}C)													
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	13.7	14.7	17.4	21.1	21	19.8	19.3	19.4	19.1	18.2	15.6	13.6	12.8
CV	1.1	1.7	2.4	0.8	0.4	0.6	0.4	0.3	0.4	1.5	2.5	1.6	0.6
Rainfall in Palakkad(mm/day)													
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Mean	8.4	9.6	23	52	97.1	180.6	165.7	133.4	111.5	176.9	111.6	31.5	1101.3
CV	225.2	264.4	905.7	1544.4	3151.7	3112	3663.9	2541.5	3693.7	5495.6	3145.4	912.5	38136.7

Source: NASA, Data Access Vie

4.11 Impact of Climate Change on Paddy Yield and its Variability.

According to Rosenzweig and Parry (1994) and Reilly et al. (1996), climate change in most developing countries is likely to be harmful and can reduce agricultural productivity. Barrios et al. (2008) argued that inter-annual and intra-annual climatic variations have a large long-term negative impact on agricultural output in poor nations. Climate change has impact on Indian economy at large (Kumar and Parikh, 2001), and its variability causes large-scale droughts and floods, which have a significant impact on Indian food grain production (Parthasarathy et al.1988; Selvaraju 2003; Kumar et al., 2004).

With reference to Kerala agriculture, there have been a large number of studies attempted to unravel the current issue of agriculture from various dimensions. Agriculture's productivity is severely hampered by technological, institutional, and resource constraints. Poor policies, socio-economic, institutional, and technological failures have been identified as the primary culprits in much of the literature on this topic. See, for instance, a few such studies are Thomas (1996, 2011); Varkey (2004) Nikhil et al. (2009); Sheeba et al. (2015); Athira et al. (2016) and Kumar et al. (2021). In general, little research has been done on how climatic variability affects Kerala's agricultural production. In the final section of this chapter, an attempt is made to highlight the impact of climate change on paddy yield and variability.

4.12 Climatic Variability on Crop Yield.

The impact of climate change on crop yield is mainly studied under two approaches. The first approach is the agronomic model which stimulates climatic variables on crop yield in an experimental setup. The benefit of this integrated crop-climate impact assessment is that it simulates a hypothetical situation and crop growth by using controlled and randomised climatic conditions. However, this method does not take into account farmers' adaptation options to changing climatic conditions. Therefore, this approach may result in an overestimation of the impact of climate change on crop yield.

The second approach called the Ricardian approach considers farm-level adaptations while assessing the impact of climate change on crop yield through their impact on farmland values (Mendelsohn et al, 1994, 1996). The main limitation of this method is that it does not take into account "time-independent location-specific factors such as unobservable farmer skill and soil quality". Although the panel data model is used to overcome omitted variable biases inherent in the Ricardian model, it does not include the farmers' long-term adaptation and crop diversification measures.

Chen et al. (2004) and MacCarl et al. (2008) were the first to use the Just and Pope stochastic production function to estimate both the mean and variance of crop yield. To estimate the effect of climatic factors on paddy yield, the present study employs the stochastic production function approach developed by Just and Pope. The estimation of the Just and Pope production function involves two steps. In the first step, yield is considered as a dependent variable where the effect of input or environmental factors has a different effect on yield and the variability of yield as measured by the standard deviation is estimated. In the second step, the standard deviation of yield is used as the dependent variable to measure the effect on yield variability. The present study used 30 years of data for yield and climate variables for the analysis. The study takes into account data of paddy yield (measured as production per hectare) from 1990 to 2020 for Kerala, as well as data on monthly average temperature, which is the average of the monthly maximum and minimum temperatures, and monthly total rainfall for the same period.

Furthermore, 11 districts fall under the coastal region in the west (low altitude), 13 districts fall under the middle land region between the west and east (mid-altitude), and 13 districts fall under the mountainous and high range area (high altitude). Because ten districts out of fourteen fall into three altitude regions, district altitude classification of climate sensitivity is difficult.

4.13 Model Specification

To study the effect of rainfall and temperature on the mean and variance of paddy yield for Kerala, Wayanad and Palakkad, the study used the Just and Pope production function. Just and Pope's production function has two parts: one is concerned with output level, and the other is concerned with output variability. The specification of production function takes in Koundouri et al. (2005) as the following form

$$y = f(X,\beta) + h(X,\alpha)\varepsilon \ldots\ldots\ldots \text{(1)}$$

Where, y = measure of output, f(.) = the production function and h(.) the risk function associated with X, X = vector of input and β, α are parameters to be estimated in connection with f(.) and h(.) Koundouri et al. (2005).

The empirical model of the Just and Pope production for the study can be specified as $Pyield_t = \beta_0 + \alpha_i + \beta_1 Parea_t + \beta_2 SRain_t + \beta_3 StdevRain_t +$

$$+\beta_5 STemp_t + \beta_6 STemp.SRain_t + \beta_7 trend_t + h(X,\alpha_i)\varepsilon \ldots\ldots\ldots(2)$$

Where, $Pyield_t$ is paddy yield in the year t which is a dependent variable. The area under paddy ($Parea$), season-wise average rainfall ($SRain_t$), season-wise average temperature ($STemp_t$), the standard deviation of rainfall for each season ($StdevRain_t$), the interaction of average rainfall with the average temperature for every season ($STemp.SRain_t$), and linear trend variable ($trend_t$). "Standard deviation of rainfall mean rainfall with mean rainfall within each season is used to control the intra-seasonal effect of rainfall on" paddy "yield and its variability". The time trend variable in the model serves as a proxy variable for the technological progress which resolves the problem of trend in some of our variables. Furthermore, rainfall and temperature for each season are included in the model to capture the differences in the impact of climate change across seasons. Furthermore, the model includes the interaction terms of rainfall and temperature during each season, implying that a given amount of rainfall can have a different impact if it is associated with changing temperature levels during each season.

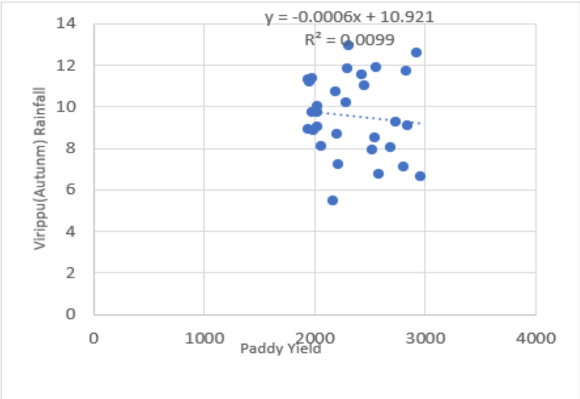
4.14 Relationship between Seasonal Rainfall and Paddy Yield

The scatter plotting diagram was used to examine the link between paddy yield and seasonal climatic variables. Rainfall during Mundakan (winter paddy season) and Puncha (summer paddy season) has a positive effect on paddy yield, as shown in figure 4.10 (b) and (c). Rainfall during the summer is critical for sowing and transplanting Virippu crops, as well as soil preparation for paddy cultivation. Paddy cultivation in the winter season is common with the arrival of the northeast monsoon, and thus rainfall is very beneficial in increasing the yield of Mundakan paddy. However, as figure 4.10 (a) shows, rainfall during virippu has a negative impact on paddy yield. Although rainfall at the end of the summer contributes significantly to paddy cultivation for autumn paddy, any excess rainfall during the rainy season causes soil erosion and flood situation in Kerala, hence depressing paddy productivity.

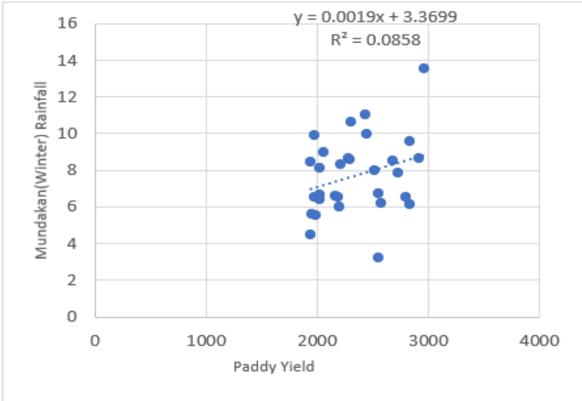
On the other hand, it has been observed from the figure 4.11 that, the temperature during all seasons had a positive effect on the yield of paddy. Seasonal minimum temperature and paddy yield show a positive relationship, whereas except for virippu paddy season, seasonal maximum temperature and paddy yield shows a positive relationship (figure 4.12). This kind of temperature is helpful for the increase in paddy yield as it leads to a better developmental stage through photosynthesis.

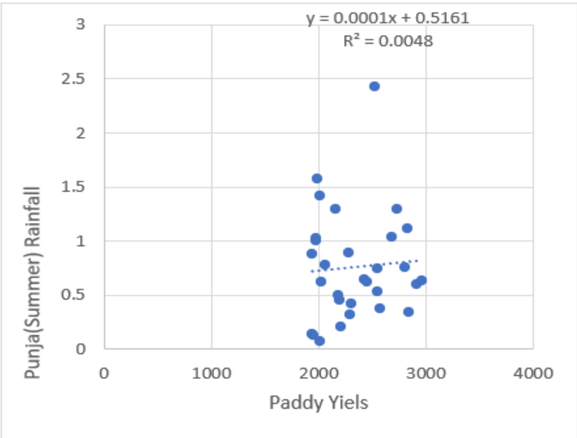
Figure: 4.10 Relation between Rainfall and Paddy Yield

(a)



(b)





(c)

Figures: 4.11 Relation between Seasonal Temperature and Paddy Yield

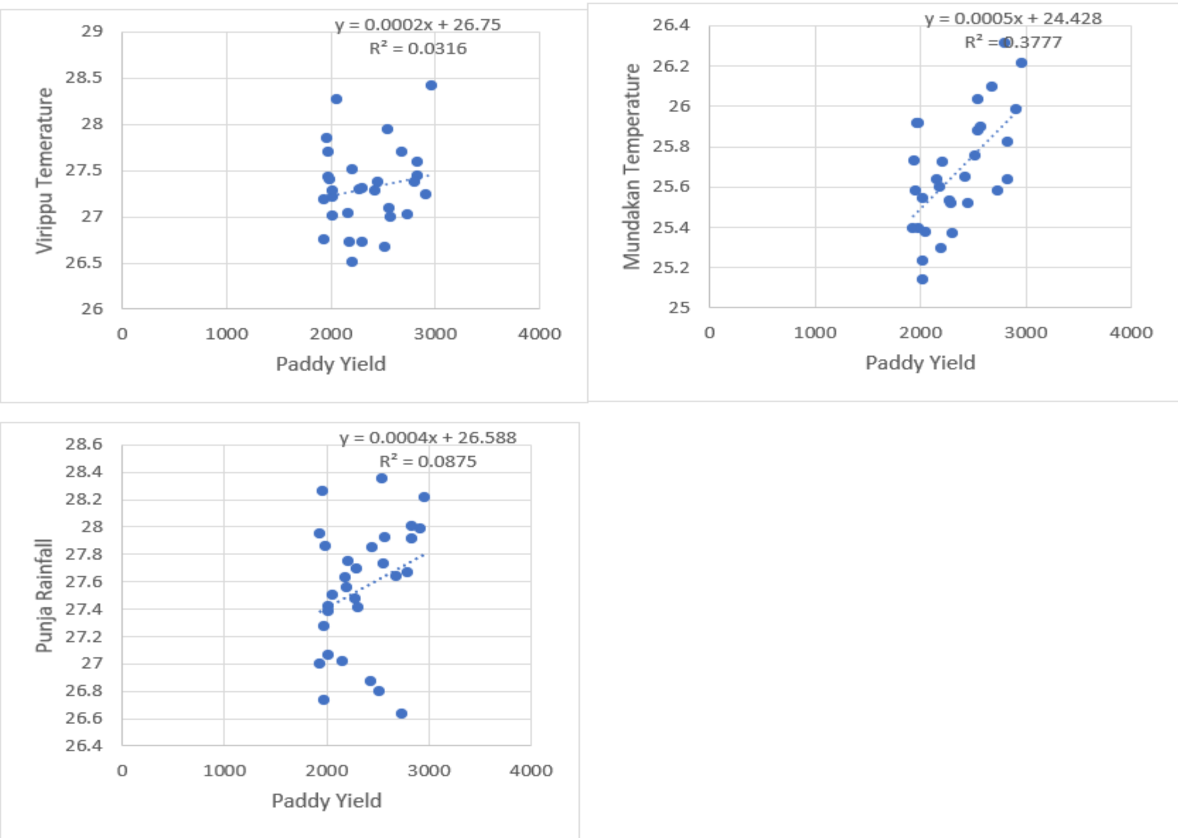
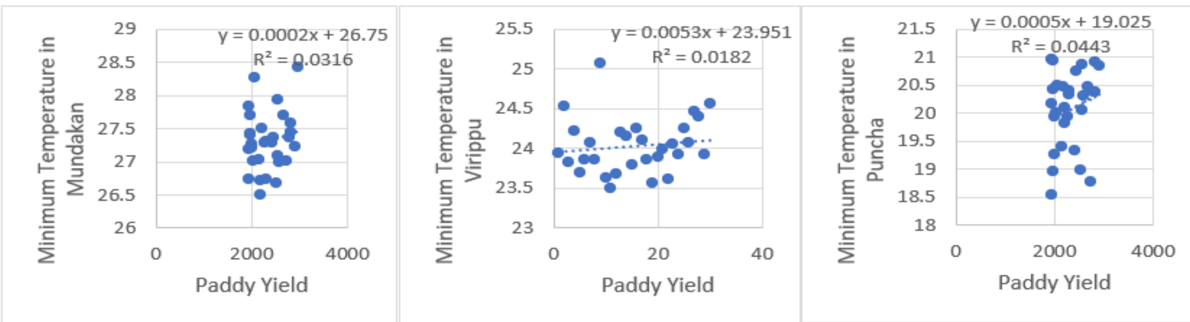


Figure: 4.12 Relation Between Minimum and Maximum Temperature and Paddy Yield

Seasonal Minimum Temperature and Paddy Yield



Seasonal Maximum Temperature and Paddy Yield

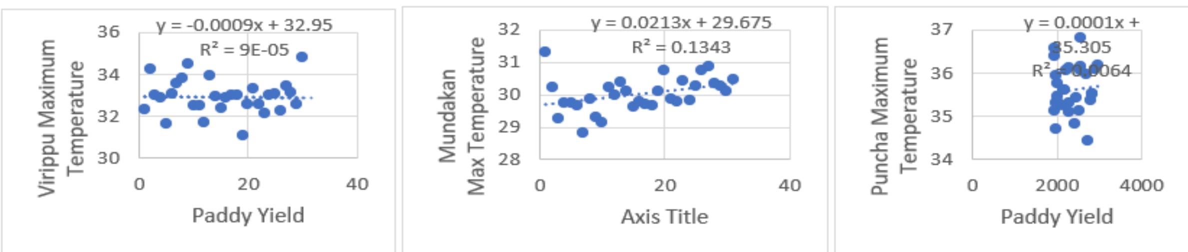


Table: 4.16 Estimated Result of the Mean and Variance Regression Model.

Variable	Mean regression model		Yield variance regression Model	
	Co-efficient	t-stat	Co-efficient	t-stat
Paddy area	0.002101	0.959	-0.00145	-1.265
Winter Rain	**0.000102****	0.652	-0.002154	-0.48916
St Dev Winter Rain	-0.0006	-0.485	-.012458	-0.12485
Summer Rain	-0.00321	-2.50	-0.6354	-0.01451
St Dev Summer Rain	-0.00513	-2.18	0.002548	0.4808
Autumn Rain	-0.00058	-0.202	-0.5687	-0.0745
St Dev Autumn Rain	**-0.00047***	1.452	-0.4258	0.21345
Summer Temp	**0.5241*****	5.65	**0.6958*****	1.54632
Autumn Temp	**-0.02851***	2.258	**-0.32698****	-0.65249
Winter Temp	**0.06136****	1.956	-0.8070	-0.1524
Winter Rain x Winter Temp	0.000213	-0.235	0.002158	-0.3654
Summer Rain x Summer Temp	0.01214	1.963	0.000256	-0.0124
Autumn Rain x Autumn Temp	1.2354	0.153	0.000235	2.0125
Trend	**1.21****	7.54	**0.2035*****	0.0315
No of observation	30			30
F stat	5.501			1.63
R-squre	0.421			0.432
Prob	0		0.00236	

Source: Author calculation from Primary data, Note: ***, **, * indicate 1 %, 5% and 10% percent respectively.

The table 4.16 shows the estimated result of the mean and variance yield regression model. The mean regression model results show that higher winter and summer temperatures increased paddy yield significantly. The temperature during these sessions is critical for the drying, growing, and harvesting of paddy crops. Furthermore, the greater standard deviation of autumn rainfall (south-west season rainfall) had a significant native effect on paddy yield. This is because uneven rainfall distribution during the rainy season has a negative impact on paddy yield, particularly if excess rainfall occurs during the flowering and grain formation phases and prolonged drought occurs during the vegetative growth stage. The variance regression model's estimated result for the coefficient for autumn and summer temperature suggests that summer temperature has a significant positive effect on paddy production variability, whereas autumn temperature has a significant negative impact on paddy yield variability. A positive linear trend coefficient in both the mean and variance models indicates that paddy yield and variability have increased significantly over time. Because the trend variable represents technological progress, technological advancement has a positive impact on the mean paddy yield and its variability

4.15 Conclusion

The present chapter analysed changing context of paddy cultivation in Kerala. In general, the studies reviewed challenges to paddy cultivation in Kerala due to socio, economic, and technological factors. The environmental factors in the form of climate change are also the important emerging challenges to the paddy cultivation in Kerala. Paddy sector to be sustainable, it needs to cope and adapt to the climate change. Changing context of paddy cultivation in Kerala in the present chapter is analysed under, socio-economic and demographic changes, technological changes, crop diversification and commercialisation, geographical, environmental and climate change. The impact of climate change on paddy yield and its variability is also looked into.

The number of agricultural labours and cultivators has decreased over the census years 2000 to 2011. Non-availability of full-time labours in paddy cultivation with higher wages in other sectors is causing the labour shortage in the study area. Paddy cultivation through padashekhara samithies and leased cultivation of paddy by the Joint Liability Group may be considered the important institutional changes in the paddy cultivation in the study area.

It has been observed that although the majority of the farmers of Wayanad and Palakkad adapted to commercial crops or other tree crops, a smaller number of farmers are found to adapt to climate-resilient practices such as altering cropping patterns towards less water required crops. With declining paddy area and production, intensive cultivation with high yielding varieties of seeds could maintain higher paddy productivity in the state. The expansion of area under high yielding seed varieties in the future depends on how far new seed verities can address climatic stress in the future.

The analysis of the impact of climate change on paddy cultivation using the Just-Pope production function shows that winter rain and the temperature in the winter and summer seasons had a significant impact on paddy yield whereas autumn temperature has a negative effect. The variability model shows autumn temperature had negative effects and summer temperature had positive effects on the paddy variability. The coefficient for the time trend is significant for both models implying technology had positive effects on both yield and its variability.

CHAPTER 5

ADAPTATION PRACTICES AND COPING STRATEGIES TO CLIMATE CHANGE BY PADDY FARMERS IN WAYANAD AND PALAKKAD

5.1 Introduction

The present study was carried out in the Panamaram Community Development Block (CDB) of Wayanad district and Kuzhalmannam and the Alathur CDB block of Palakkad district. From the analysis of the previous chapter concerning the current issue of Kerala agriculture, it is clear that ongoing climate change may be a risk factor to Kerala agriculture in general and paddy cultivation in particular. The climate change risk appeared as one of the most challenging issues among many other crises to the paddy cultivation (KSAPCC, 2008, 2014). In addition to the adjustment to many other vulnerabilities, paddy farming to be sustainable is required to cope and adapt to climate change (FAO, 2016). Therefore, the present chapter attempts to analyse how far paddy farming is sustainable in the context of climate change. Paddy farming may be sustainable in climate change when adaptation and coping strategies adopted by paddy farmers contribute to improving technical efficiency.

This chapter deals with paddy farmers coping strategies and adaptation practices to climate change and their impact on the technical efficiency in the Wayanad and Palakkad districts. This chapter has four sections. The first section discusses the general characteristics of paddy farmers' households and the distribution of paddy farmers based on their socio-economic features. The second section looks at the distribution of paddy farmers based on their perceptions of climate change. Paddy farmers' adaptation practices, and coping strategies in the study area are discussed in the third section. The final section examines impact of adaptation practices and coping strategies on the technical efficiency of paddy farming in the study area. Technical efficiency among various classification of factors and the comparison of the efficiency of paddy cultivation in the context of "adaptation practices and coping strategies" in the Wayanad and Palakkad study area is also discussed in the subsection.

5.2 The General Description about the Study Area

Wayanad is one of the south Malabar districts with a border with two states of Tamil Nadu and Karnataka. The district has the largest tribal population formed on 1^{st} November 1980 as the 12^{th} district of the state by carving out area from Kozhikode and Kannur districts. The district lies between the North latitude of 11^0 26' to 12^0 00' and East longitude of 75^0 75' to 76^0 56'. It is a picturesque plateau situated between 700 and 2100 meters above the mean sea level. Despite being a backward district, Wayanad contributes foreign exchange through the production and export of cash crops such as pepper, cardamom, tea, coffee, and other spices.

Table: 5.1 Administrative Particulars of Wayanad and Palakkad

	Numbers in Wayanad	Numbers in Palakkad
Revenue Division	1	2
Taluks	3	5
Revenue Villages	49	163
Municipalities	1	4
Block Panchayath	4	13
Grama Panchayath	25	90
Assembly Constituencies	3	12
Parliamentary constituency	1	2
Total population	743494	2809934

Source: Census of India, 2011, District Hand Book

Wayanad is thought to have derived its name from two vernacular words: '**Vayal'** means paddy field and '**Nadu'** means land, which together means 'land of paddy field.'[23].The term 'Vaazha Naadu' means 'land of banana field also etymologically correct in the changing agricultural environment of Wayanad, where rapid shifts in cropping pattern and conversation of paddy field towards banana cultivation. However, despite the difference in opinion about its etymology, it is a historical fact that the region had plenty of paddy fields.[24]

[23]KKN Kurup, paniyas of Wayanad, 2008, Sultan Bathery
[24] Wayanad District HDI Report (2009)

Palakkad District was established as an administrative unit on January 1, 1957. The administrative headquarter is Palakkad, and it is spread over 26.60 sq km. The district has 5 Taluks, 4 Statutory Towns,17 Census Towns,13 Community Development Blocks and 91 Panchayats(Palakkad Census, 2011). Wayanad has the largest ST (18%) population, whereas Palakkad has the highest SC (14%) population to the district population. Palakkad is called “the rice bowl of Kerala” because of its largest net sawn area under paddy cultivation.

The average maximum and minimum temperatures in Wayanad are 35°C and 16.5°C, respectively. During the southwest monsoon season, humidity levels in Wayanad and surrounding areas can reach 95 per cent. The district of Wayanad receives approximately 300 mm of rain per year on average. Palakkad has a tropical climate that is both wet and dry. Except for the hottest months, March and April, temperatures remain moderate throughout the year. Palakkad receives unusually high precipitation, owing primarily to the Southwest monsoon. July is the wettest month, with an average annual rainfall of about 83 inches (210 cm). The total forest area of Wayanad is 78787 ha, representing 36.9 % of the total geographical area of the district (Agricultural Statistics, 2020). The district is divided into two physiological regions the Wayanad plateau and forest hill. Brahmagiri (1608 metres), Banasura peak (2073 metres), and Chembra peak are all major mountains in Wayanad (2100 meters).

The Palakkad district is Kerala's largest, covering 11.5 per cent of the state's land area. The total forest area of the Palakkad is 136257 ha, constituting 30.4 % of the total geographical area of the district (Agricultural Statistics, 2020). Many of the small and medium rivers in the district are tributaries of the Bharathapuzha river. Several dams, the largest of which is the Malambuzha dam, have been built across these rivers. The district is divided into two natural divisions based on physical characteristics: midland and highland. Valleys and plains define the midland region. It leads to the highlands, which contain high mountain peaks, longspurs, enormous ravines, dense woods, and tangled jungles. While Ottappalam taluk is totally in the midland region, the remaining taluks in the district are evenly divided between the midland and highland zones. Except for two peaks above 6000 feet, "the Western Ghats have an average elevation of 5000 feet. Anginda peak (7628 ft), Karimala peak (6556 ft), Nellikotta or Padagiri peak (5200 ft), and Karemala Gopuram are the important peaks above 4000 ft (4721 ft.)". (kerala.gov.in). Details of administrative units in Palakkad and Wayanad is given in Table 5.1

Map: 5.1 Wayanad District

Source: www.mapsofindia.com

Map: 5.2 Palakkad District

Source: www.mapsofindia.com

Kabani and its three major tributaries, Panamaram Puzha, Manathawady Puzha and Baveli Puzha, and seven minor tributaries drench and flow through Wayanad. Panamaram Puzha, for example, traverses a vast distance through human settlement from its beginning. Kabani is a major tributary of the Cauvery River. Kabani is one of Kerala's east-flowing rivers. Wayanad's Banasura Sagar dam, built entirely of earthen materials, is the largest in India and the second largest in Asia, built on Kabani streams. The Banasura Sagar project provides irrigation and drinking water and support for the Kakkayam Hydroelectric Power Project. Karapuzha irrigation is the first and major project in the district that support water for the cultivation of mainly paddy, vegetable and other crops.

Palakkad districts have five rivers, as Bharathapuzha, Kannadipuzha, Gayathripuzha, Thuthapuzha, Kalpathipuzha, which wet an excellent part of the agriculture field. It is the only district with having a good number of irrigation facilities in Kerala. There exist around 15 dams across all tributaries of Bharathapuzha exclusively for irrigating paddy fields. Walayar, Malampuzha, Cheerakuzhi, Gayathri, Mangaldam, Pothundy are the six out of ten completed irrigation projects in Palakkad. These five-irrigation project alone has a total of 77306 Ha of ayacut. Moreover, Chitturapuzha, Kanjirappuzha has 54200 Ha of ayacut are the other two irrigation projects in Palakkad under progress.

Table: 5.2 General Details of Sample

	PALAKKAD		**WAYANAD**	
	Frequency	%	Frequency	%
Total number of people	837		629	
Male	422	50.4	314	49.9
Female	415	49.6	315	50.1
Educated	797	95.2	580	92.2
Illiterate	40	4.8	49	7.8
Higher educated	394	47.1	253	40.2

Source: Primary Survey. April, May 2021

The present study covered 1466 persons who live in paddy farm households. There are 837 household members in Palakkad and 629 members in the Wayanad study area. There are 422 males and 415 females in Palakkad and 314 male and 315 females in the Wayanad study area. The literacy rate among paddy farm households in the study area is 95.2 % and 92.2 %, respectively, in Palakkad and Wayanad study areas. The number of illiterates is less in Palakkad than in Wayanad, whereas the number of higher educated is more than in the Wayanad study area.

While looking at the types of households, it is clear from Table 5.3 that a traditional joint family structure appropriate for paddy cultivation from the Wayanad study area is rapidly disappearing. Traditionally joint family setups have supplied major parts of family labour to the laborious paddy farming operation. However, it is found that; there are only 8.6 % of paddy farmers reside in joint family-based households in Wayanad. Nuclear and extended type of family set up is relatively more among paddy farmers' households in Wayanad than in Palakkad. In contrast, Palakkad study area nuclear and extended type family is less, whereas the joint family set up is found more.

Table: 5.3 Household Type

	Wayanad		Palakkad	
Household type	Frequency	%	Frequency	%
Nuclear	71	51.1	32	16.7
Extended	56	40.3	75	39.1
Joint	11	8.6	85	44.3

Source: Primary Survey. April, May 2021

The analysis of data from paddy farm households based on their occupational structure, such as major, medium, and minor, reveals that, out of 1466 persons in the sample study area, 202 from Palakkad and 202 from Wayanad received paddy cultivation is the major occupation. Agriculture and allied activities are among the most important medium occupations in Palakkad. Private service is a major occupation in both Wayanad and Palakkad, whereas other casual labour is a major, medium, and minor occupation in both sampled study areas. For 38 people in Wayanad, government service is a major occupation, but for only 13 people in Palakkad. Agriculture labour

Table: 5.4 Occupational Structure

Occupations	Palakkad			Wayanad		
	Major	Medium	minor	Major	medium	Minor
Cultivators	200	39	7	202	85	2
Allied Agricultural Activities	13	84	27	2	1	1
Agricultural Labour	2	1	1	1	0	0
Other labour	23	26	18	85	38	4
Household industry	2	0	0	0	0	0
Trade or business	9	8	0	23	5	0
Govt service	13	1	0	38	0	0
Pvt Service	61	2	0	59	0	0
MGNREGA	7	26	39	2	9	4
Other	72	3	8	5	1	0

Source: Primary Survey. April, May 2021

is not a significant occupation in either study area, possibly because the majority of farm households use direct cultivators. In Palakkad, trade and business were discovered to be major occupations. MGNREGA is found to be included as a medium or minor occupation only in both

Wayanad and Palakkad; even so, it is observed as a cause of concern for the labour shortage in paddy cultivation.

5.3 Land Holding Size.

In the Palakkad sample study area, out of 192 samples; there are 48.4 % small and marginal farmers having less than 1 acres of land, 43.2 % medium farmers having landholding in between 1 to 4 acres, whereas 8.4 % of them are large farmers having land holding greater than four acres. The majority of the paddy farmers in Palakkad are either small/marginal or medium-size farmers. In the Wayanad study area, out of the 138 sample paddy farmers, 27 of them (19.6 %) are small and marginal farmers, 28 (20.3 %) of them are large farmers, whereas 83 of them are (60.1 %) medium-size farmers. In short, the majority of the paddy farmers in Palakkad sample study area are either small/marginal or medium-sized, whereas those in Wayanad are medium-sized. Furthermore, large-sized farmers are relatively found more in the Wayanad study area than in Palakkad.

Table: 5.5 Size of Land Holding

Size of Land Holding(acres)	**Palakkad**		**Wayanad**	
	No of Farmers	%	No of Farmers	%
Small and marginal <1)	93	48.4	27	19.6
Medium (1-4)	83	43.2	83	60.1
Large >4	16	08.4	28	20.3
Total	192	100	138	100

Source: Primary Survey. April, May 2021

Agriculture land use may be classified in the sample study area such as leased in cultivation, owned cultivation, operational holding, area cultivated in Kharif and Rabi, total cropped area, irrigated and unirrigated area. From table 5.6, leased-in cultivation of paddy crops is carried out in 230.78 acres of land, which constitute 37.1 % of total operational holdings in Wayanad. Kudumbashree based leased cultivation of paddy crop is widely observed in the Wayanad study area. It has been observed from the field that special incentives given for barren or fallow land conversion to paddy cultivation promoting paddy cultivation by Joint Liability Groups. Paddy procurement at higher minimum support prices, special subsidy for paddy cultivation encouraging Kudumbashree based leased in paddy cultivation in the study area. Leased in paddy cultivation assume less importance in the Palakkad sample study area; it constitutes only 9.1 % of total operational holding.

The Wayanad sample study area has 389.83 acres under-owned cultivation, whereas the Palakkad sample study area, it has 288.1045 acres area. Palakkad study area mostly practices monocropping, and the total cropped area is 572.634 acres which mostly stems from paddy crop only. Whereas gross cropped area in Wayanad is 681.92 acres despite paddy crops is cultivated only once a year. Wayanad study area has a higher gross cropped area mainly because it practices mixed cropping and homestead-based farming. Wayanad sample study area mostly practices rainfed farming. Wayanad has 201.34 acres irrigated area and an unirrigated 181.77 acres of area.

Table: 5.6 Agriculture Land Use

	Palakkad	Wayanad
Leased in cultivation	29.07	230.78
Owned Cultivation	288.1045	389.82
Operational holding	317.1745	620.6
Area cultivated in Kharif	285.902	314.85
Area cultivated in Rabi	286.732	0
Gross cropped area	572.634	314.85
Irrigated area	263.082	201.34
Unirrigated	49.22	181.77

Source: Primary Survey. April, May 2021. Note: Area in acres

Important sources of irrigation in the study area are ponds, streams, lift irrigation, canal, dug well, and river can be seen in table 5.7. Dug well, natural streams and lift irrigation are found to be important sources of irrigation for the majority of the paddy farmers in Wayanad. Only 5 to 8 paddy farmers have access to the river, and canal-based sources of irrigation in the Wayanad sample study are. Since the Wayanad sample study area is mostly rainfed, inadequate canal irrigation facilities constrain paddy cultivators to do a second crop in a year. It is observed from

Table: 5.7 Sources of Irrigation

	Wayanad	%	Palakkad	%
Pond	18	13.0	21	10.9
Stream/rainfed	76	55.1	62	32.3
Lift irrigation	60	43.5	36	18.8
Canal	5	3.6	174	90.6
Dug well	110	79.7	150	78.1
River	8	5.8	32	16.7

Source: Primary Data, April, May 2021

the study area that farmers used to do paddy cultivation twice a year when canal irrigation and lift irrigation facilities were provided by the public authorities. However, farmers now cultivate paddy only once a year after the damage of canal and lift irrigation facilities in the Wayanad study area.Whereas, in the Palakkad study area, 174 paddy farmers out of 192 samples, 90.6 % have canal irrigation facilities as a source. The river, stream, lift irrigation are also fount important sources of irrigation in the Palakkad sample study area. In contrast to the Wayanad sample study area, the Palakkad study area has mostly irrigated by canal facilities; hence, farmers can cultivate paddy twice a year.

5.4 Status of Paddy Production in the Study Area

In the Palakkad study area, paddy farmers can do paddy cultivation for the second crop season due to the presence of sufficient canal irrigation facilities. The total area under paddy cultivation during the first crop is 297.85 acres and produces 578838 kilograms of paddy. The productivity of paddy in the study area during the first crop season is 1520.9 kilograms per acre which is less than the district average. During the second crop season, the Palakkad sample study area has 286.732 acres under paddy cultivation and produces 616154-kilogram of paddy output. Productivity of paddy during the second crop season is more than the first crop because of irrigation facilities. In the Palakkad sample study area, some farmers do not have access to canal irrigation n even during the second crop season. Hence area under paddy is a little less than that of the first crop season. Nevertheless, the productivity of paddy in Palakkad is found more in the second crop than that in the first crop.

Table: 5.8 Area, Production and Productivity of Paddy

Study Area	First Crop Paddy Area (Acre)	First Crop Paddy Output (Kg)	First Crop Yield (Kg/Acre)	Second Crop Paddy Area (Acre)	Second Crop Output (Kg)	Second Crop Paddy Yield (Kg/Acre)
Palakkad	317.7915	483360	1520.9	286.732	619154	2159.3
Wayanad	297.85	578838	1943.3	Nil	Nil	Nil

Source: Primary Data, April, May 2021

Wayanad's study area is entirely dependent on rainfall. Hence cultivate paddy only once a year. Only five paddy farmers out of 138 sample farmers were found to have access to canal irrigation. The area under paddy cultivation in the Wayanad study area is 297.85 acres, and the total production of paddy is 578838 kilograms. The productivity of paddy is 1946.3 kilograms per acre in the Wayanad sample study area, which is less than average district productivity.

5.5 Farm Specific Characteristics in the Study Area

Table 5.9 gives farm-specific characteristics in the sample study area**.** It has been found that the Wayanad study area has 85.5 % male heading in paddy cultivation and whereas in Palakkad sample study area has 74 %. Wayanad sample study area has a greater number of paddy farmers who derive farm income from livestock ownership. In both Wayanad and Palakkad sample study areas, more than 90 % of farmers have contact with extension services. More farmers in Wayanad sampled study is found to have an awareness of climate change than the Palakkad sample study area. More farmers from the Wayanad sample study area have access to loans to the Palakkad sample study area. The majority of the farmers from both study areas derive income from off-farm activities.

Table: 5.9 Farm Specific Efficiency Factors

	Wayanad		**Palakkad**	
Variables	No of Farmers	%	No of Farmers	%
Gender (Male farm head)	118	85.5	142	74.0
Farm income livestock from ownership	88	63.8	53	27.6
Extension contacts	131	94.9	175	91.1
Awareness of Climate change	129	93.5	149	77.6
Access to loan	136	98.6	166	86.5
Off-farm income	84	60.9	155	80.7
Temperature	129	93.5	182	94.8
Rainfall	123	89.1	96	50.0
Use of Modern Technology	75	54.3	41	21.4

Source: Primary Data, April, May 2021

It has also been found that 75% of paddy farmers from Wayanad agree that they are using modern technology in farming, whereas only 21 % of the sample from the Palakkad area use modern technology.

5.6 Paddy Farmers Specific Efficiency Factors in the Study Area.

In the Palakkad and Wayanad study area, the average years of education of the paddy farmers is nine years. Similarly, both study area has four members as the average size of the households. The average age of the farmers in Wayanad is 55 years, whereas Palakkad is 59 years. The average years of experience of the paddy farmers in Wayanad are 32 years, whereas Palakkad is 27 years. It has been observed in the study area that many of the farmers in the Palakkad study area are attempting to get inputs, especially seeds from the research station, which are found to have (25 k.m to 65 k.m) far distanced places like Koyambathur and Thrissur, Kanchikode. Therefore, the average distance is found to be more in the Palakkad study area than that of Wayanad. In the case of distance to output market, for the majority of the farmers in both study area, there exist on-site government procurement of paddy. However, few farmers in both study areas market paddy output in the open market to avoid delay in payment & receipts via government procurement. In that case, the average distance to farmers in the output market in Wayanad is 3.1 k.m, whereas that for Palakkad is 3.5 k.m.

Table: 5.10 Summary Statistics of the Farmer Specific Socio-Economic Characteristics

	Wayanad			Palakkad		
	Mean	Max	Mini	Mean	Max	Mini
Average Years of Education	9	17	1	9	15	0
Household Size	4	11	1	4	10	1
Age (Years)	55	80	22	59	83	29
Experience (Years)	32	70	1	27	69	1
Distance to Input Market (Km)	3.4	25	0.5	7	60	0
Distance to Output Market (Km)	3.1	6	0.5	3.5	8	1

Source: Primary Data, April, May 2021

5.7 Paddy Farmers Perception about Climate Change

The present study examines paddy farmers' perceptions of climate change before analysing the farmers' "technical efficiency" effects of "adaptation practices and coping strategies" to climate change. The study used variables like 'years of climate change awareness', whether agreed or disagreed about the existence of ongoing climate change, perception about changes in the average rainfall and the temperature, ranking perception of various climate change factors.

Table: 5.11 Perception about Ongoing Climate

Climate change is	Palakkad	%	Wayanad	%
Happening	152	80.7	110	79.1
Not happening	40	19.3	28	20.9
Total	192	100	138	100

Source: Primary Data, April, May 2021

Before analysing the effects of climate change-induced decisions made by paddy farmers, it is necessary first to understand their perception of ongoing climate change. Therefore, the present study attempted to examine paddy farmers' perceptions of climate change from a different perspective, as detailed in Table 5.11. When asked whether they agreed about ongoing climate change, 110 out of 138 farmers in Wayanad and 152 out of192 farmers in Palakkad sample study areas have agreed. At the same time, approximately 20% of paddy farmers in both study areas disagree on whether climate change is occurring. Surprisingly, in both study areas, the percentages of paddy farmers who agreed or disagreed that climate change was occurring were roughly equal. When farmers are asked to describe a climate-change-related incident, they will mention a flood, drought, heavy rains, a decline or delay in rainfall, a weed or wildlife attack. However, when asked to describe climate change, a few farmers got it wrong, as evidenced by their explanation of ozone layer depletion, which they even associated with the end of the world!

Farmers were subjected to two climate change stimuli, temperature and rainfall, to understand their perception of climate change better. Farmers were then solicited on their thoughts on temperature and rainfall deviations from the long-term average . For example, in the case of temperature, how far farmers perceived long-term average temperature changes from the current level. Whether it is increasing, decreasing, stable/regular, or irregular. Details are given in table 5.12. It was found that 182 out of 192 farmers in Palakkad and 117 out of 138 farmers in Wayanad perceived a temperature increase above the long-term average. For both the study areas, there were very few perceived changes in the temperature pattern is decreasing, stable, or irregular. Farmers in both study areas have varied perceptions of changes in ongoing rainfall patterns. In Palakkad, out of 192 samples, 96 farmers perceived an increasing nature of present rainfall from the long-term average, 47 perceived a decreasing nature of present rainfall from the long-term average, 21 perceived normal rainfall patterns, and 28 perceived irregular nature of changes in ongoing rainfall pattern from the normal rainfall . In Wayanad, out of 138 samples, 70 farmers perceived an increasing nature of present rainfall from the long-term average, 32 perceived a decreasing nature of present rainfall from the long-term average, 16 perceived normal rainfall pattern, and 20 perceived irregular nature of changes in ongoing rainfall pattern from the normal rainfall .

Table: 5.12 Perception about Climate Change Anomaly

Palakkad				**Wayanad**			
Temperature		Rainfall		Temperature		Rainfall	
Increasing	182	Increasing	96	Increasing	117	Increasing	70
Decreasing	3	Decreasing	47	Decreasing	6	Decreasing	32
Stable	5	Stable	21	Stable	11	Stable	16
Irregular	2	Irregular	28	Irregular	4	Irregular	20
Total	192	Total	192	Total	138	Total	138

Source: Primary Data, April, May 2021

Garrett ranking techniques are used in the present study to determine the most crucial climate change factor perceived by paddy farmers. Farmers were asked to rank several alternatives regarding climate change factors to determine which climate change factors dominate farmers' perceptions . Farmers, for example, were asked to rank the following climate change factors in order of importance .

1. Temperature changes
2. Excess rain
3. Incidents of droughts
4. Incidence of flood
5. Decline in rainfall
6. Delay in rainfall
7. Growing season changes
8. Extreme weather events
9. Forest fire
10. Landslide

In the Garret ranking technique, the paddy farmers' rankings are first converted into score values with the following formula.

Percent position = $100(R_{ij}-0.5)/N_j$, Where,

R_{ij}= Rank given for the i^{th} factor by the j^{th} respondent.

N_j= No of factors ranked by the j^{th} respondent.

Table: 5.13 Dominant Factors in Climate Change Perception

Climate Change Factors	Garret Mean Score	Rank	Climate Change Factors	Garret Mean Score	Rank
Palakkad			**Wayanad**		
Higher average Temperature	62.9	1	Incidents of droughts	58.4	1
Excess Rain	59.1	2	Higher average Temperature	55.1	2
Incidents of droughts	58.6	3	Excess Rain	54.6	3
Incidence of Flood	53.7	4	Incidence of Flood	54.0	4
Decline in Rainfall	51.3	5	Decline in Rainfall	50.0	5
Delay in rainfall	50.9	6	Growing Season Changes	42.6	6
Growing Season Changes	42.7	7	Extreme Weather events	41.3	7
Extreme Weather events	42.6	8	Delay in Rainfall	26.0	8
Forest Fire	21.9	9	Forest Fire	10.0	9
Land Slide	20.01	10	Land Slide	0.02	10

Source: Primary Data, April, May 2021

After listing the frequency of the factor ranking, the per cent position is converted into scores by referring to the Garret table. The scores of each individual are then added for each factor, yielding average scores The selection of important climate change factors according to Garrett ranking method is given in table 5.13. A higher average temperature is the dominant climate change incident in farmers' perception. Drought and excess rainfall are two other major climate events that influence paddy farmers' views on climate change in the Wayanad and Palakkad study areas. Other significant climate change factors viewed by paddy farmers in the study area include flood incidents, a decrease and delay in rainfall, and a change in the growing season. The study area's least perceived climate change events are forest fire and a landslide.

5.8 Adaptation Practices and Coping Strategies

One of the primary goals of this research is to evaluate paddy farmers' adaptation practices and coping strategies in response to perceived changes in the climate. Adapting to climate change refers to "adjusting to actual or anticipated climatic stimuli to reduce risk and taking advantage of opportunities that arise from such actions, with a long-term goal in mind" (Author et al., 2021)[25].

[25] "Effect of adaptation to climate change on technical efficiency of paddy farmers in Panamaram" NVEO, (2021) Basheer K K, G Sridevi. The some of the result of the case study for Wayanad district is published in the said journal as part of the present research.

On the other hand, coping strategies reduce risks due to climatic variability, primarily with a short-term goal. There is literature regarding foreign countries that attempts to evaluate the effects of agricultural adaptation practices on the efficiency of agriculture. Most research combines adaptation and coping strategies, with no distinction between adaptation practices and coping strategies. The present study attempted "to distinguish between adaptation practices and coping strategies before examining their individual effects on the efficiency of paddy cultivation in the study area" (Author et al., 2021)[26].

Table 5.14 and figure 5.15 describe the most "commonly used coping strategies by the paddy farmers" * in the Wayanad and Palakkad sampled study area. It has been found in the Wayanad study area that making delays in sowing is the most commonly used coping strategy. Many paddy farmers adopted the delay in sowing because of the late arrival of the monsoon. About half of the farmers in a Wayanad study area adopted "direct sowing, crop insurance, and shifting from long to short maturing verities". * Whereas in the Palakkad study area, more than 90 % of farmers adopt

Table: 5.14 Common Coping Strategies by Paddy Farmers

Coping strategies	No of farmers in Wayanad	%	No of farmers in Palakkad	%
Adoption of drought-tolerant verities	64	46.4	99	50.0
Application of drip irrigation method	14	10.1	0	0.0
Summer Ploughing	69	50.0	191	96.5
Direct Sowing	83	60.1	82	41.4
Transplanting	25	18.1	186	93.9
Continuous Cropping	43	31.2	187	94.4
Crop Insurance	70	50.7	148	74.7
Shifting from long to short-duration varieties	70	50.7	97	49.0
Increased irrigation facilities.	48	34.8	69	34.8
Delayed sowing	96	69.6	105	53.0

Source: Primary Data, April, May 2021

summer plaguing, transplanting, and continuous cropping. The same percentage of paddy farmers from Wayanad and Palakkad adopted interchange between short and long duration varieties and

[26] (ibid)
*Technical terms used in the work of [26] "Effect of adaptation to climate change on technical efficiency of paddy farmers in Panamaram" NVEO, (2021) Basheer K K, G Sridevi

increased irrigation facilities as a coping strategy to climate variability. The drip irrigation method is the least adopted coping strategy in the study area.

Figure: 5.1 Common Coping Strategy

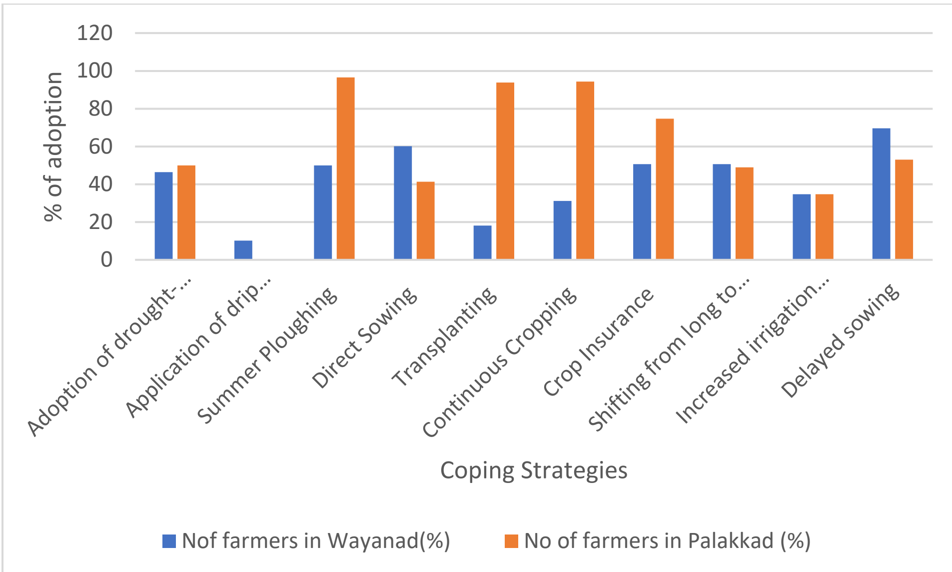


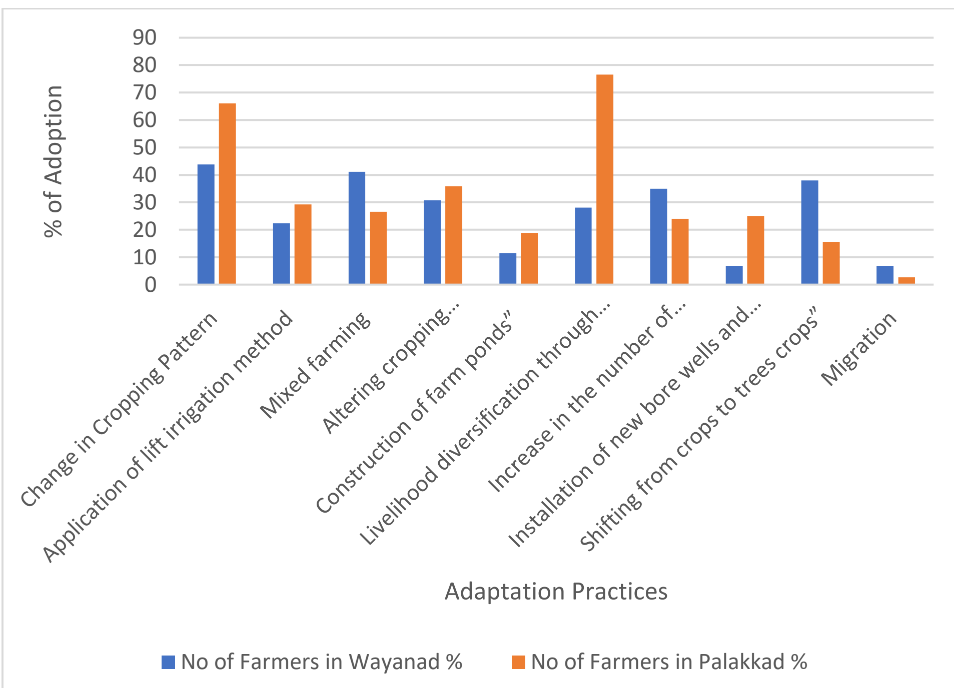
Table 5.15 describe the most commonly used adaptation practices in the Wayanad and Palakkad study area. Change in the cropping pattern and livelihood diversification through increased non-farm employment are the most commonly used adaptation practices in the Palakkad study area. A smaller number of paddy farmers in Palakkad are building farm ponds and switching from crops to tree crops. Changes in cropping pattern, mixed cropping, switching from the crop to tree crops are important "adaptation practices" in the Wayanad study area. In the Wayanad study region, a smaller number of paddy farmers practise the construction of farm ponds, wells, and borewells. Migration is the least adopted adaptation practice in Wayanad and Palakkad study areas.

Table: 5.15 Common Adaptation Practices by Paddy Farmers

Adaptation Practices	No of Farmers in Wayanad	%	No of Farmers in Palakkad	%
Change in Cropping Pattern	84	43.8	127	66.1
Application of lift irrigation method	43	22.4	56	29.2
Mixed farming	79	41.1	51	26.6
Altering cropping patterns to less water-intensive or rained crops.	59	30.7	69	35.9
Construction of farm ponds	22	11.5	36	18.8
Livelihood diversification to non-farm employment	54	28.1	147	76.6
Increase in the number of livestock	67	34.9	46	24
Installation of new bore wells and wells	13	6.8	48	25
Shifting from crops to trees crops	73	38	30	15.6
Migration	13	6.8	50	2.6

Source: Primary Survey, April, May 2021

Figure: 5.2 Common Adaptation Practices



5.8.1 Complementary Adaptation Practices and Coping Strategies by Paddy Farmers

In the context of climate change and variability, farmers need to adapt and cope with many strategies and practices. Since adaptation practices and coping strategies are not substitutable, complementary in adaptation practices and coping strategies is likely to increase the efficiency of paddy production (Author et al., 2021). Complementary in practices and strategies means the ability of the farmers to undertake more than one strategy and practice to adjust to climate change and variability . Therefore, the present study analyses "complementary adaptation and coping strategies" in the sample study area. Table 5.16 discuss complementary adaptation and coping strategies in the sample study area.

In the case of complementary adaptation practices in the Palakkad study area, 4.2 % of paddy farmers in the sample adopt no adaptation practices, whereas only 3.1 % of farmers adopt at least seven different adaptation practices in their single farms. There are 30 % of paddy farmers in Palakkad who adopt at least three adaptation practices at their farms. More than 60 % of farmers adopted at least 3 to 6 adaptation practices in the Palakkad study area. Complementary adaptation practices in Wayanad show that most farmers adopted 3 to 7 adaptation practices . There are only

Table: 5.16 Complimentary Adaptation Practices & Coping Strategies

Number Of Adaptation Practices /Coping Strategies Used	**Complementary Adaptation Practices**				**Complementary Coping Strategies**			
	No of farmers in Palakkad	%	No of farmers in Wayanad	%	No of farmers in Palakkad	%	No of farmers in Wayanad	%
10	0	0	0	0	0	0	0	0
9	0	0	1	0.7	5	3.6	5	2.6
8	0	0	7	5.1	16	11.6	31	16.1
7	6	3.1	18	13	23	16.7	39	20.3
6	12	6.3	27	19.6	35	25.4	43	22.4
5	20	10.4	32	23.2	34	24.6	49	25.5
4	34	17.7	33	23.9	14	10.1	21	10.9
3	59	30.7	13	9.4	10	7.2	3	1.6
2	34	17.7	7	5.1	1	0.7	1	0.5
1	19	9.9	0	0	0	0	0	0
0	8	4.2	0	0	0	0	0	0

Source: Primary Data, April, May 2021

seven farmers who adopted at least 8 number of adaptation practices in Wayanad and seven farmers adopted only 2 number of adaptation practices in the Wayanad study area. None of the Palakkad study region farmers used all of the “complementary coping strategies”. In the Palakkad research area, just one farmer used two coping methods, and only five farmers used a maximum of nine coping strategies. Majority of the farmers adopted at least 3 to 8 coping strategies in the Palakkad study area. Complementary coping strategies in Wayanad reveal that no farmer has ever used all of the coping strategies on their farm simultaneously. Only one farmer in Wayanad used a minimum of two coping strategies. Similar to the Palakkad study area, only five farmers used nine coping techniques in the Wayanad study area. In the Wayanad sample study area, the majority of the farmers used 4 to 8 coping techniques.

5.9 Determinants of Efficiency of Paddy Cultivation

One of the specific objectives of the present study is to understand the technical efficiency effect of adaptation practices and coping strategies to climate change by paddy farmers in the Wayanad and Palakkad districts of Kerala. The present section devoted to the analyses of this objective end in view. Before going into the details of efficiency effects of climate change adaptation and coping strategies, summary statistics of paddy output and various inputs used in paddy cultivation in the Wayanad and Palakkad sample study area is discussed

The current study used the total kilograms of paddy obtained by the farmer in a year to calculate paddy output. Due to difficulty obtaining data on paddy straw, this aspect of output is excluded. Total production, area and yield of paddy season-wise have already been discussed under the section of the present chapter's 'status of paddy production. The status of paddy production in the study area is discussed in table 5.17.

Table: 5.17 Production and Area under Paddy in Study area

	Area Under Paddy (Acer)	Paddy Output (Kg)	Yield Per Acer
Palakkad	604.5235	1102514	1840.1
Wayanad	297.85	578838	1943.3

Source: Primary Data, Authors calculation. April, May 2021

It is clear from table 5.17 that the total production of paddy comes from the cultivation of paddy in two seasons in a year for the Palakkad sample study area, whereas paddy production happens only one season in the Wayanad sample study area. The total area under paddy cultivation in the

Palakkad sample study area is 604.5235 acres, and production is 1102514 kilograms of paddy in 2020-21 agriculture year. Whereas for the Wayanad sample study area, the area under paddy and production is respectively is 297.85 acres and 578838 kilograms of paddy.

Summary statistics of output and various inputs used in paddy cultivation, socio-economic farm-specific factors and adaptation and coping strategies used have been given in table 5.18.

Table: 5.18 Summary Statistics of Output and Various Inputs in The Stochastic Frontier Production Function

Variables	Wayanad (No of observation138)				Palakkad (No of observation 192)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Paddy Output(kg)	4194.5	5719.6	500.0	55660.0	5767.9	6510.2	350.0	46000.0
The area under paddy (Acer)	2.2	2.7	0.3	25.3	3.0	3.2	0.4	23.4
Seed (kg)	72.5	116.3	6.0	1163.0	129.8	168.2	14.0	1800.0
Total human labour (Man days)	71.0	59.8	7.5	379.5	239.4	869.0	26.0	11827.0
Organic Fertilizer(kg)	1575.5	1689.8	0.0	10000.0	998.4	1774.9	0.0	15000.0
Inorganic Fertilizer(kg)	243.0	318.6	0.0	2530.0	556.6	559.9	35.0	36000.0
Total Machine Labour (Hours)	18.2	24.1	2.8	227.7	21.3	33.8	2.0	410.0
Plant Protection(liters)	0.9	2.4	0.0	25.0	0.9	1.1	0.0	7.0
Technical Efficiency Factors								
Education(years)	9.1	2.9	1.0	17.0	9.0	3.7	0.0	15.0
Household Size	4.5	1.8	1.0	11.0	4.3	1.9	1.0	10.0
Age (years)	55.1	10.8	22.0	80.0	59.7	11.0	29.0	83.0
Experience (years)	32.6	15.0	1.0	70.0	27.3	17.3	1.0	69.0
Complementary Adaptation practices	5.1	1.5	2.0	9.0	3.2	1.6	0.0	7.0
Complementary Coping Strategies	5.8	1.5	2.0	9.0	6.1	1.4	2.0	9.0

Source: Primary Data, Authors calculation. April, May 2021

The Cobb-Douglas stochastic frontier model with inefficiency effect is used in the present study to investigate the impact of climate change adaptation and coping methods on the technical efficiency of paddy farming. Maximum Likelihood Estimate of (MLE) for the parameters are given in table 5.19. In both Wayanad and Palakkad study areas, farm size has a highly significant influence on the output of paddy cultivation. In the Wayanad sample study region, estimated parameters significantly impact paddy production, except for machine labour and plant protection. Except for labour in man-days, seeds, manure, machine labour, and plant protection have all demonstrated positive effects on paddy productivity in the Palakkad research area, though not statistically significant at the one per cent level. Return to scale is estimated to be less than one, indicating that paddy cultivation in both sampled research areas has a diminishing return to scale.

Table: 5.19 Maximum likelihood Estimate of (MLE) the Stochastic Frontier Production Function

	Wayanad		**Palakkad**	
Production Model				
Variables	Coefficients	P>IzI	Coefficients	P>IzI
Farm Size	0.91202	0	0.7445	0
Labour (Man days)	0.1484	0	-0.05	0.174
Seeds (KG)	0.03002	0	0.0789	0.151
Manure (K.G)	0.0306	0	0.050507	0.0775
Machine Labour (Hours)	-0.195	0	0.1149	0.069
Plant Protection (Litters)	-0.001	0	0.045237	0.168
Return to scale	0.92504		0.984044	
Efficiency model				
Education Level	-0.09002	0	0.025646	0.437
Household Size	0.009297	0	-0.06233	0.131
Age	-0.4467	0	-0.08366	0.436
Experience	0.054863	0	0.07466	0.001
Adaptation Practices	-0.008	0	-0.02587	0.289
Coping Strategy	0.32	0	-0.05825	0.467
Diagnostic Parameters				
Mean technical inefficiency	-0.1645	0.002	-0.17	0.66
Insigma2	-2.31	0	0.2988	0.893
Igtgama	29.3	0.801	5.1771	0.02
Sigma2	0.098727		2.9873	
Gamma	1		0.012455	
Sigma_u2	0.0987		2.9872	
Sigma_v2	1.69E-14		0.001719	

Source: Primary Survey. Author Calculation

The efficiency model shows inefficiency effects exist because $\gamma = 1$ in the case of Wayanad study area and $\gamma > 0$. (γ is called gamma ratio explain variation in frontier output on account of farm-specific factors and adaptation practices and coping strategies adopted by the paddy farmers, if technical inefficiency is present in the model, γ ration will be lies between greater than zero and less than one.).

The efficiency model shows that inefficiency exists in the model because $\gamma = 1$ in the case Wayanad study area and $\gamma > 0$ in the case of the Palakkad study area. The estimated coefficients for education, age, and adaption practises in Wayanad are negative and significant. When paddy farmers are receiving more and more years of education, they can better manage farm operations and increase awareness of improved input quality, which reduces inefficiencies. In Wayanad, the estimated parameters for age are negative and significant, meaning that as farmers get older, their abilities in performing various farm operations improve over time, reducing technical inefficiency. The estimated parameters for complementary adaptation strategies are also negative and significant, implying a more potent combination of alternative adaptation techniques used on individual farms, improved farm adaptability to climate change, and reduced paddy production inefficiency.

For Wayanad, estimated parameters such as household size, experience, and coping techniques are positive, implying that increasing any of these factors increases technical inefficiency. As household size increases, anticipation of future fragmentation of landholding may affect the operation of current paddy cultivation, reducing farm production efficiency in the Wayanad study area. Contrary to the expected relationship between experience and technical inefficiency, the present study found a positive and significant relationship in the Wayanad study area . The fact that the estimated coefficient for complementary coping strategy is found positive and significant suggests that the complementary coping methods used by paddy farmers in their fields may not be a good mix of tactics, thereby increasing inefficiency in the Wayanad research area.

Estimated parameters for the production model with reference to the Palakkad district show that only farm size significantly affects paddy output. Although not significant, all other inputs used except labour man-days positively affect the paddy output. Palakkad paddy output production is subjected to constant returns to scale at 0.984. as the coefficient value. Estimated parameters for the inefficiency model with reference to the Palakkad study area shows that household size, age, adaptation, and coping strategies adopted have a negative but not significant impact on the technical inefficiency in paddy cultivation. It implies that an increase in factors such as household size, age, combined adaptation and coping strategies has positive effects on increasing efficiency in paddy cultivation. At the same time, education level and experience positively impact the technical inefficiency in the Palakkad study area compared to the Wayanad study area. However, not significant adaptation practices and coping strategies adopted have more effects on increasing paddy cultivation efficiency. However, with reference to the Wayanad study area, adaptation strategies significantly increase the technical efficiency of paddy cultivation.

5.10 Efficiency of Paddy Farmers Based on Socio-Economic and Climatic Factors

After estimating the MLE of the production model, efficiency model, and technical inefficiency scores of individual paddy farmers, the present study attempted to conducted cluster analysis of the paddy farmers to determine which category of farmers is more efficient. Classification of technical efficiency scores of the paddy farmers in the study area based on gender, social groups, education, farm size, awareness about climate change, adopters and non-adopters of adaptation and coping strategies is given in table 5.20. Male-headed paddy farmers in Wayanad and Palakkad are efficient and significant, whereas female-headed paddy farmers are inefficient and significant in Palakkad and inefficient and not significant in Wayanad. The average technical efficiency scores among social groups show that scheduled tribe and scheduled caste paddy farmers in Wayanad, as well as OBC category paddy farmers in Palakkad, are inefficient and significant. Technical efficiency scores among various educated categories show that primary educated paddy farmers are efficient and significant; on the other hand, higher educated paddy farmers are significantly inefficient for both study areas. Paddy farmers' higher educational attainment may have contributed to diversification into non-farm employment activities, lowering their efficiency scores. The average technical efficiency score of small and marginal farmers is higher than the average technical efficiency score of large and large farmers, supporting the existing notion of a trade-off between farm size and efficiency.

The classification of paddy farmers based on their technical efficiency based on climatic factors reveals that the majority of farmers in both study areas who agree on the existence of ongoing climate change have higher average efficiency scores and although not statistically significant. Paddy farmers from both study areas perceive higher average ongoing temperature is significantly efficient. Farmer perceived excess rain fall pattern also found efficient but not significant. Paddy farmers adopt various adaptation practices, and coping strategies to climate change in the Palakkad study area is found relatively more efficient than the Wayanad study area.

Table: 5.20 Technical Efficiency Scores of Paddy Farmers Based on Socio-Economic and Climatic Factors

Factors	Average Technical efficiency Score	
	Wayanad	Palakkad
Gender		
Male	0.56**	0.78**
Female	-0.51	-0.64**
Social groups		
SC/ST	-0.41**	-0.57
OBC	-0.69	-0.78**
General	0.81	0.66
Education		
Primary	0.49**	0.77**
Secondary	-0.81	-0.8
Higher secondary	-0.75	0.44**
Higher educated.	-0.34**	-0.71**
Farm Size		
Small Farmers <1 Acre	0.91**	0.77**
Medium Farmers 1 to 4 acres	0.64	0.84
Large Farmers >4 acres	-0.55**	-0.63**
Climatic factors		
Awareness about climate change	0.79	0.81
Temperature	0.83**	0.87**
Rainfall	0.64	0.46
Adaptation practices	0.39**	0.62**
Coping strategies.	-0.55**	0.74**

Source: Primary Data, Authors Calculation Note: ** at 5% significance level. Figure without stars are all at 10 % level of significant

5.11 Conclusion

The present research has chosen Wayanad and Palakkad as the primary study area to study “the effects of adaptation practices and coping strategies in paddy cultivation”. Incorporation of technical efficiency effects of adaptation practices, in general, is emerging in this area of research; however, “the separate treatment of the adaptation practices and coping strategies in technical efficiency analysis is the first attempt in this field of research” (Author[27] et al., 2021). Before examining the effects of climate change adaptation strategies on the efficiency of paddy cultivation in the study area, the study investigated paddy farmers' perceptions of climate change from various perspectives. When the majority of the paddy farmers agreed on the existence of ongoing climate change “with an increase in long-term average temperature; episodes of droughts and floods, excessive rain, and the decline and delay in the arrival of rainfall were the climate change aspects that dominated the paddy farmers perception”(ibid).

Although the adoption rate is lower, delaying sowing is a popular coping method used by paddy farmers in Wayanad, but summer is a problem for paddy farmers in Palakkad. Changes in cropping patterns are common adaptation methods used by paddy farmers in Wayanad in response to climate change, whereas diversification of livelihood towards non-farm employment is common in Palakkad paddy farmers. When just 30% of paddy farmers in Palakkad use three “complementary adaptation practises”, only 23% use four “complementary adaptation practises” in Wayanad. In the case of coping strategies, only 25 % of paddy farmers adopt six “complementary coping strategies” in Palakkad, whereas 25 % of paddy farmers in Wayanad adopt five “complementary coping strategies”. The adoption of certain adaptation practices depends on the type of supplemental support services provided by the public bodies.

Only in the case of Palakkad paddy farmers do the efficiency impacts of coping techniques work better. In contrast, both coping and adaptation strategies enhance the efficiency of paddy cultivation in the Palakkad sample study area, but statistically insignificant. In the Wayanad research area, climate change adaptation measures on paddy farm efficiency are positive and significant, but the influence of coping strategies is negative and significant.

[27] “Effect of adaptation to climate change on technical efficiency of paddy farmers in Panamaram” NVEO, (2021) Basheer K K, G Sridevi. The some of the result of the case study for Wayanad district is published in the said journal as part of the present research.

CHAPTER-6

SUMMARY, CONCLUSION AND MAJOR FINDINGS

A growing body of scientific studies published by various reports of the Intergovernmental Panel on Climate change (IPCC) since the 1990s undoubtedly concluded that ongoing climate change is real and anthropogenic. In connection with climate change, it has been observed in different parts of the world that changes in average global temperature, variability in the local rainfall pattern, melting of polar icecaps and resultant sea-level rising with the drowning of coastal areas, shifting of local ecological zones, in addition to the extreme climatic events such as drought and flood in many parts of the world. Every economic sector will be adversely affected by the ongoing climate change; however, the agricultural sector is particularly vulnerable to climate change as it is climate dependent and sensitive sector where the majority of the population in the world directly derives livelihood from it. Adaptation and mitigation to climate change are the two significant policy responses to climate change. The present study is carried out against this background of climate change issues and sustainable development in agriculture as its counterpart.

Although the issue of climate change and sustainable development is an emerging area for scientific inquiry, ongoing research has been given inadequate attention to assessing agriculture's performance, especially when adaptation practices and coping strategies are included in the decision-making process. The present study is carried out to understand the performance of paddy cultivation in Kerala state. Under this objective, the study attempted to analyse the performance of agriculture in terms of changes in the land use pattern and cropping pattern in general for the Kerala state. The same analysis is carried out for comparative study for Wayanad and Palakkad of Kerala. Specifically, the status of paddy production in Kerala state to Palakkad district (top performing district for paddy production in Kerala) and Wayanad district (one of the least performing districts in Kerala) is analysed. Secondary data since 1990 is used for the comparative study of the area, production and productivity changes in paddy crop for Kerala state and with Wayanad and Palakkad districts.

Analysis of land use pattern for the Kerala state in general shows that, agriculture land use pattern particularly net swan area, and gross cropped are is declining in Kerala for the period under study, whereas land put to non-agriculture purpose nearly doubled. Climate change-induced crop failure perhaps causes a decline in profitability of using land for agriculture purposes and conversion of the same for real estate and other commercial building purposes. Land use pattern changes in the Palakkad district show similar tendencies to changes observed in Kerala state, whereas Wayanad district shows a different picture in the net sown area where it is marginally increased for the period under study.

Analysis of the changes in the cropping pattern in Kerala shows that there have been significant changes in the cropping pattern of Kerala from the production of paddy-based food grains production to plantation and coconut-based non-food crops. Similar to the observed shifts in the cropping pattern in Kerala, Palakkad district also experienced the change from food crops to non-food crops. Cropping pattern changes in Wayanad show a similar trend where there are visible shifts in the area from cultivating paddy-based food crops to non-food crops, predominantly plantation crops.

Analysis of production of essential crops in Kerala shows a negative growth rate is experienced for all crops except for tea and rubber, particularly for the period between 2005-09. Unlike several negative growth years recorded concerning important commercial crops and plantation crops in the case of Kerala and Palakkad, Wayanad district recorded a smaller number of negative growths with reference to those crops. Wayanad district is famous for producing plantation crops such as tea, coffee and, to a lesser extent, rubber. However, Wayanad districts could not maintain their stable growth pattern of plantation crops.

As part of the study's first objective, the comparative status of paddy cultivation is analysed in terms of area, production, and productivity with reference to Kerala state and Palakkad and Wayanad districts. The analysis shows that rice production in the state experienced an increasing rate of negative growth from -0.55 per cent in 1985-90 to -4.16 per cent until 1995-99, the negative growth rate in rice production declined -1.03 per cent in 2005-09. It has been noticed that 1.46 per cent growth rate of rice production in 2010 for the first time since 1985 in Kerala. This growth in rice production has been attributed to various promotion policies of rice cultivation by the state government and the adoption of specific adaptation practices such as the System of Rice Intensification (SRI) in various parts of the state. Although several negative growths recorded in the case of rice production in Palakkad district is lesser as compared to the state level, the growth rate of rice production in Palakkad declined from 3.1 per cent in 1985-89 to -0.03 per cent and stood at 1.62 per cent growth in 2010-14 and this growth rate for Palakkad is still more significant than the state average.

As part of the study's first objective, the present study attempted to analyse the cost efficiency of the paddy cultivation for Kerala state for the 19-years panel data. The stochastic frontier estimates results show significant cost efficiencies in human labour and machine labour use in paddy cultivation in Kerala. At the same time, cost inefficiencies exist in estimated parameters for seeds, fertiliser and machine labour for the period under study. The emergence of the employment guarantee programme has resulted in an acute labour shortage in paddy cultivation has perhaps led to efficient use of labour remaining in paddy cultivation. Subsidised seeds and fertiliser coupled with non-familiarity with mechanisation, especially in paddy cultivation, may be resulted in the inefficient use of these inputs.

Analysis of the demographic changes from the 2001 and 2011 census data, it has been noted change in the category of workers from agriculture labour, cultivators to other category; affecting the labour availability to paddy cultivation in Kerala, Wayanad and Palakkad. Labour shortage in the study area is not only caused by the availability of alternative local jobs with higher wages, but also the emergence of MGNREGA, seasonal nature of agriculture jobs, shifting to permanent occupation, perception of agriculture occupation as low esteem, higher educational attainment and occupational mobility, migration to other cities and the foreign countries. Paddy farmers deal with the issue of labour shortage in a variety of methods in the study area, including collective farming through Padashekhara Samithies and Kudumbasree-based leased in cultivation. Crop diversification decreases the risks associated with crop production owing to climate variability, but commercialization helps farmers reduce high paddy cultivation expenses and labour shortages. Crop diversification as a climate change adaptation, on the other hand, necessitates a shift in crop mix that is climate robust, which is lacking in the study area. The shift to modern paddy seed varieties such as Uma, Athira, and Kanjana, which are more resilient to climate change factors, has been observed as an indicator of technological adaptation to climate change by paddy farmers in the study area.

Against the changing background of paddy clavation, climate change factors pose one of the severe threats to the sustainability of the paddy cultivation. It has been observed significant rainfall and temperature variability both for the seasonal and annual data set for Kerala, Wayanad and Palakkad. Using the Just pope production function, the analysis of the impact of the climatic variability on the paddy yield indicates variability of rainfall during the autumn season has adverse significant effect on the paddy yield. Higher minimum temperature during winter and summer season has positive effect on the paddy yield.

At present, Kerala state has a shortage of around 84.46 per cent of rice compared to the total requirements. In general, the poor performance of Kerala's agriculture sector and paddy cultivation, in particular, has been linked to several causes. Some studies identify that declining profitability forces cultivates to move away from paddy cultivation. Some argue that the lucrative construction sector with a high job opportunity and higher wages attracts more labour from paddy cultivation. Others study views the booming of the real estate and construction sector due to high foreign remittance, leading to conversion of paddy wetland to non-agriculture purposes. However, O'Brien (2000) and Jørgensrud (2014) argued that trade liberalisation and climatic vagaries subjected farmers to multiple exposures to vulnerabilities, worsening the agrarian crises. Since (Deshpande, 2010), extreme climatic conditions such as drought have resulted in crop failure and debt traps, causing a large number of farmer's suicide in states such as Andhra Pradesh, Marathwada of Maharashtra and different parts of Kerala. Changes in the temperature and rainfall pattern also influence the area, production, and productivity of thermo-sensitive crops predominantly grown in high altitude regions (KSAPCC 2008). SAPCC (2014) projects that paddy production will drop by 6% to each degree rise in the temperature.

Price and non-price factors and recently associated with climatic variability may be identified as reasons for this dismal performance of paddy cultivation in Kerala. In climate change, the agriculture sector needs to be sustainable and adverse effects of future climate change can be reduced when it can adapt and cope with climate change. Climate change-induced adaptation and coping strategies used by farmers may improve the efficiency of cultivation. Although the literature is emerging in this direction with reference to foreign countries and very few with reference to Indian agriculture, none of the studies attempted in Kerala agriculture. Therefore, the present study attempted to capture the performance of paddy cultivation in Kerala in terms of technical efficiency effects of climate change-induced adaptation practices and coping strategies.

The specific objective of the present study is to understand the effects of paddy farmers' "adaptation and coping strategies" to climate change on the "technical efficiency of paddy cultivation". "Stochastic frontier production function" analysis has been used to assess the performance of paddy cultivation. The use of this method in the present study has the following two advantages. "Firstly, it is assumed in the study that paddy farmers who adopt various coping strategies and adaptation practices are likely to be more efficient. Therefore, it is possible to measure inefficiencies in paddy cultivation due to variations in the coping strategies and adaptation practices adopted by the paddy farmers. Another advantage is that such analyses bear policy implications for improving efficiencies by considering better adaptation options to climate change. In other words, suitable adaptation practices that improve paddy cultivation efficiency can be identified" *[28].

The uniqueness of the present study is that complementary adaptation practices and coping strategies adopted at the farm level have been taken as independent variables in the stochastic frontier estimation. Primary data is collected from the Palakkad and Wayanad district of Kerala state for the micro-level analysis. These are the two most vulnerable districts of the state to climate change according to climate change hotspot analysis of the Kerala State Action Plan on Climate Change. Out of the total 330 samples,

*[28] "Effect of adaptation to climate change on technical efficiency of paddy farmers in Panamaram" NVEO, (2021) Basheer K K, G Sridevi. The some of the result of the case study for Wayanad district is published in the said journal as part of the present research.

138 and 192 samples from Wayanad and Palakkad were included in the study by the multi-stage random sampling method.

Before going to a major analysis of specific objectives of the present study, socio-economic characteristics of the study area, production of paddy, cost of production of paddy, farm-specific factors that affect technical efficiency of paddy cultivation, perception of paddy farmers about climate change, climate change-induced adaptation and coping strategies adopted by the paddy farmers have been summarised in the study. Complementary adaptation practices and coping strategies adopted by the farmers are calculated to include additional variables influencing the paddy cultivation's technical efficiency.

Analysis of the paddy farmers' households' socio-economic characteristics shows that the literacy rate is more or less similar in both study areas. However, different family set-ups are found among paddy farmers in the Wayanad and Palakkad study areas. On the one hand, the typical joint family set-up suitable for paddy cultivation is fast disappearing, whereas nuclear type family set-up is found more in the Wayanad sample study area. It is just the opposite found in the Palakkad study area. There are almost the same percentage numbers of paddy farm households in extended type families set up in both sampled study areas.

The occupational structure of the farm household in Wayanad and Palakkad shows that cultivation, govt service, private services, other casual labour and trade and business are the major occupation. The existence of medium occupation in agriculture and allied activities, other casual labour, participation in employment guarantee programmes helps paddy farm households diversify family income sources.

The present study adopted a different way of classifying farmers on their landholding size due to a smaller number of sample units for analysis. Analysis of the landholding size shows that most of the paddy farmers in Wayanad are small and marginal, having less than one-acre holding, whereas the majority of the paddy farmers are either medium or large farmers having more than one acre of land in Palakkad. Agriculture land use shows that leased in paddy cultivation is 37.1 per cent of operational holding among Wayanad paddy farmers, whereas it is only 9.2 per cent in the Palakkad study area. Leased in farming in paddy cultivation is more in Wayanad because of higher procurement prices, subsidies, and other special incentives for paddy cultivation for Kudumbashree based JLG farming.

Palakkad study area mainly practices paddy cultivation based on mono-cropping, whereas mixed cropping and homestead-based farming are mainly practiced in the Wayanad study area. Most of the area under paddy cultivation in the Palakkad is irrigated by the canal, whereas modern irrigation facilities by canal and others are grossly inadequate in the Wayanad study area. Wayanad used to cultivate paddy twice a year; however, the shortage of rainfall in crop season and inadequate irrigation facilities in the Wayanad study area constrain paddy farmers to carry out paddy farming even once a year. Although there are canal irrigation facilities, the productivity of paddy is relatively lower in the Palakkad study area; perhaps paddy based monocropping for each season for years have reduced the soil fertility. In the case of the Wayanad study area, paddy cultivation is possible only once a year, and hence the second season mostly remained as fallow. Therefore, seasonal crop interval between paddy seasons coupled with mixed farming and homestead-based farming in the Wayanad study area supports paddy farming. It may be the reason for the relative higher productivity of paddy in Wayanad.

Analysis of the farm-specific characteristic shows that majority of the paddy farmers are male-headed, although female-headed paddy farmers are relatively more in the Palakkad study area. More paddy farmers have access to credit and derive income from livestock ownership in Wayanad than the Palakkad study area. However, the majority of the paddy farmers from both study areas derive income from off-farm activities. Most farmers in Wayanad were found aware of climate change than the Palakkad study area. More than 90 per cent of farmers have contact with extension services in both sampled study areas.

Paddy farmers in both study areas have, on average, nine years of education and four members as the average size of the household. Palakkad study area has paddy farmers with 27 years as average experience, whereas, in Wayanad, it is 33 years. The average age of the paddy farmers is 55 and 59, respectively, for Wayanad and Palakkad study areas. In terms of distance to the input market, it has been found that only very few farmers could able to procure the latest and good quality seeds from long distanced research stations. To avoid delay in payment and receipt of income from paddy output from government procurement programme, few farmers resort to open market sale of paddy output. Some farmers mainly leased in paddy cultivators are forced to rely on the open market sale of paddy output because tenant cultivator leases primarily without a formal agreement with the owner.

Prior to analysing climate change-induced adaptation practices and coping strategies adopted by the paddy farmers, the present study attempted to look into paddy farmers' perceptions of climate change from a different dimension. It has been found unity on agreement among paddy farmers from both study areas about the ongoing climate change. It has been replied by 79 per cent, and 81 per cent paddy farmers respectively from Palakkad and Wayanad study area for the question on the existence of climate change. The majority of the farmers from both study areas experienced an increase in the present temperature from the long-term average. The majority of the paddy farmers from Wayanad experienced excess rainfall and increasing nature of rainfall pattern from long term average. A smaller number of paddy farmers view that temperature and rainfall patterns are normal. Few farmers are accepting that rainfall pattern is irregular. The calculated result of the Garett ranking technique shows that high temperature, incidents of drought, excess rain, and flood dominate the perception of the paddy farmers about the ongoing climate change factors. The garret ranking result found consistent with three years consecutive flood happened all across Kerala since 2018, although Garett rank for the factor flood stood 4 for both study areas with little difference in terms of Garett Mean Score with other factors.

The uniqueness of the present study is the estimation of the effects of adaptation practices and coping strategies on the technical efficiency of paddy cultivation. In the context of changing climate and variability, climate change-induced adaptation and coping decision also affects the performance of paddy cultivation. Although few studies are emerging in this direction with reference to foreign countries, research on different effects of adaptation practices and coping strategies adopted by paddy farmers on their production efficiency has not been carried out. Considering the fundamental differences in adaptation practices and coping strategies adopted by the paddy farmers on their temporal ground, the present study identified variables for the study area from expert discussion and existing literature.

Coping strategies considered for the study are adopted for quick relief in response to adverse climate change. Making delay in sowing and direct seeding instead of transplanting are the two most commonly used coping strategies adopted by the paddy farmers in response to late arrival and the early departure of rainfall in the Wayanad study area. Adaptation rates among climate-specific coping strategies such as drought-resistant verities, increased irrigation facilities, crop insurance, shifting from long to short maturing verities are relatively less frequent for the Wayanad study area. Whereas summer ploughing is the most common coping strategy adopted by paddy farmers in the Palakkad study area. Although not specific to climate change adjustment practices, more than 90 per cent of paddy farmers adopted transplanting and continuous cropping coping strategies. However, climate-specific coping strategies such as drought-resistant varieties, direct seeding instead of transplanting, shifting from long to short maturing verities have lesser adoption rates. Therefore, it is imperative to be aware of specific coping strategies for paddy farmers to help them distinguish from those they conventionally adopted and those of needed strategies that perhaps contribute to increasing their production efficiencies.

However, the adaptation variable considered for the study are those practices on a temporal scale adopted for gradual adjustment in response to climate change. In general, the adoption rate among adaptation practices in the Wayanad study area is less frequent. More than 50 per cent of paddy farmers in the Wayanad study area have no adaptation practices. Except for cropping patterns and livelihood diversification changes, all other strategies are less frequently adopted in the Palakkad study area. Mixed farming and making changes in the cropping pattern are the common adaptation practices used in the Wayanad study area. In contrast, livelihood diversification through increased non-farm employment and changing cropping patterns are common adaptation practices in the Palakkad sample study area. Migration and bore-well installation for irrigation is the least used adaptation practice in Wayanad, whereas migration and change from crop to tree crop are less adopted adaptation practices in the Palakkad study area.

Since adaptation to climate change is framed for long-term end in view and has many public good benefits, there are opportunities for those adapting to climate change. The use of particular adaptation practices by farmers in the study area depends on different kinds of institutional support provided for paddy cultivation. For example, the adoption rate of the lift irrigation method in Palakkad is lesser because of adequate canal irrigation facilities; however, the adoption of the same in the Wayanad study area is also found to be lesser despite inadequate canal irrigation facilities. Therefore, to adopt adequate lift irrigation facilities by the majority of the small and marginal farmers in the Wayanad study area require the public provision of lift irrigation methods to better adapt to climate change and better enhance the productive efficiency of paddy cultivation.

In order to better resist the adversities of climate change, complementarity in coping strategies and adaptation practices reveals considerable significance because farmers need to implement adjustment practices in their farms in combination rather than to substitute between them. The present study calculated complementary coping strategies and adaptation practices as a separate variable influencing the technical efficiency of paddy cultivation in the study area. The result of the combined adaptation and coping strategies shows that none of the farmers is adopted all of the adaptation and coping strategies in the study area; however, the majority of the farmers in the study area found adopted 4 to 7 adaptation and coping strategies simultaneously in their farms.

The maximum likelihood estimates for parameters on the stochastic frontier analysis shows that, in the production model, there exist decreasing return to scale in paddy production in both study area. Inputs used in paddy cultivation such as farm size, labour, seeds, and manure in the Wayanad study area have significantly increased paddy output. In contrast, machine labour and plant protection chemical herbicide and weedicide show negative and significant impacts on paddy output.

The efficiency model for the Wayanad shows that level of education, age and various adaptation practices to climate change has significant effects on increasing the efficiency of paddy cultivation. The case of parameters like household size, experiences, and various coping strategies have decreased the efficiency of paddy cultivation in the Wayanad study area. Estimated parameters for the production model for Palakkad shows that only farm size has a significant effect on paddy output. Although not significant, except labour in man-days, other inputs such as seeds, manure, machine labour and plant protection are positive. Estimated parameters of the efficiency model for the Palakkad study area shows that, although not significant, adaptation practices, coping strategies, size of the farm households and ages of the farmers have increased the efficiency of paddy production. In contrast, experiences and education levels have decreased the efficiency of paddy cultivation.

6.1 Policy Suggestions

Over the last few years, Kerala has taken remarkable spteps to increse paddy production. However, given the enormous challenges that rice cultivation faces in the state, it is still too early to say whether these initiatives will be able to achieve entire goals. The following are some key areas where policymakers must intervene as per present research.

- The issue of shrinking paddy cultivation area on the one hand and conversion to and expansion of area for non-agricultural use on the other should be addressed by amending the existing Kerala Conservation of Paddy Land and Wetland Act, 2008.
- There is an urgent need to address the issue pertains to labour shortages by converging Kudumbshree, MGNREGS and Rashtreeya Vikas Yojana, for the revitilation of paddy cultivation in the state.
- Cost inefficiency in paddy cultivation in Kerala can be greatly reduced by substituting labour costs for material costs and providing farmers with the most up-to-date technology through Padashekara Samithies.
- The function of farmers collectives such as padashekhara samithies may be strengthened further by the responsibility of disseminating information about the early warning system with climate variability and changes to the farming community.
- It is essential to implement long-term policy programmes in the form of by strengthening canal irrigation infrastructure on a priority basis because adoption of coping strategies to climate change depends in large part on the existence of adequate adaptation policies to climate change by public authorities.

- In order to avoid conflict in their employment of complementary coping and adaptation methods to climate change, there should be an effective awareness programme for paddy farmers regarding the adoption of suitable mix of coping strategies and adaptation measures.
- The proper implementation of state sction plans on climate change may strengthen adaptation practises and coping strategies.

To sum up, the use of stochastic frontier analysis to assess the performance of paddy cultivation with primary data from the two most vulnerable climate change hotspots of Kerala- Wayanad and Palakkad is perhaps the first attempt of study. The present study is also a first attempt to incorporate separate variables for climate change-induced "adaptation practices and coping strategies" in the technical efficiency analysis. However present attempt is not without issues. Firstly, since time-series data for adaptation and coping strategies do not become available, the study resorts to qualitative data where multiple responses of the respondent have been employed to extract variables for adaptation and coping strategies. The scaling techniques with more comprehensive coverages and weighting to capture more and more accuracy in variables used for adaptation practices and coping strategies may be considered for further study in this area.

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Questionnaire for Data Collection of Sample Paddy Farmers (Households/Agriculture Labor /Cultivators), to Study Paddy farmers Adaptation to Climate Change.

1. Identification

District.	Village	Ward	Caste(Code-1)	Household Type Code-2	Religion Code-3
Code 1, (Caste (SC/ST=1, OBC=2, GN=3, Others 4), **Code 2**, (Nucleus=1, Joint=2, Extended). **Code-3**(Muslim 1, Hindu, 2, Christian 3, others 4)					

2. Basic Details of Household Members

S.No	Names	Sex (Code-1)	Age (Year)	Education (Code-2)	Occupation (Code-3)		
					Major	Medium	Minor
Code 1: Male=1, Female = 2. **Code 2**: (only for 6+years) Illiterate=1, Literate but below primary=2, Primary=3, Secondary (5 to 10 std) =4, Higher Secondary=5, Technical=6, Graduation =7, Non-formal=8. P.G = 9 **Code 3:** Cultivator=1, Allied Agricultural Activities=2, Agricultural Labor=3, Other Labor=4, Household Industry=5, Trade or Business=6, Service (Government)=7, Service (Private)=8, 9 = MNREGA 10 = House Wife, Other (Specify)=11.							

3. Assets (Farm Land, Area in Acres & Cents)

Possess Code 1	If yes area	Leased in Area	Leased out Area	Reason for leasing out **Code 2**	Dry land Area	Wet land Area	Value of sale
Code 1, Yes= 1, No=2. Code 2, Engaged in other activities=1, Longer distance from home=2, Physical disability=3, other (specify) =4**.** **Code -3**: Meeting Consumption expenses=1, Debt repayment=2, Marriage=3, Health=4, Other (Specify) =5.							

4. If land is leased-in

How long since you have been a tenant farmer?	Nature of Lease Agreement Code 1	Duration of tenancy?	Have you taken a tenant identity card?	Any loan to involve in tenancy Society?	Terms in case of share cropping
Code-1, 1=Share Cropping, 2= Fixed Rent, 3= both share cropping and fixed rent 3= Cash or kind					

5. Land Particulars Area in Hectors

Land holding status	Irrigated		Unirrigated	Total land area
	Area	Sources (code 1		
Land owned				
Fallow land				
Leased in land				
leased out land				
Total operated land(1-2-3+4)				
Area cultivated in Kharif				
Area cultivated in Rabi				
Area cultivated in Summer				
Entire Year (Annual crops)				
Size of the land holding (Code 2)				
Code1: 1=Bore well; 2= Dug well; 3 = In well bore; 4=Canal; 5= Stream; 6=Tank; 7=Lift irrigation; 8 = River, 9=Others, **Code2**: 1. Marginal less than one Acres, 2. small (less than one /equal to 2 Acres, 3. Semi medium, 4. Medium (greater than 2 Acres and less than/equal to 5 Acres, 5. Large (greater than 5 Acres)				

6. Assets (Livestock)

Description	Do you possess now (Yes=1, No=2)	If yes, Number	Sold in last year (Yes=1, No=2)	Value of Sale(Rs.)	Reason for Sale (Meeting consumption Expenses=1, Debt=2, Marriage=3, Health=4, Flooding = 5, Drought= 6, Other (specify)=5
Bullocks					
Cow					
Buffalo					
Sheep/Goat					
Poultry/Birds					

7. Housing Characteristics

Ownership (Code-1)	Number of Rooms	Access to Electricity (Code-2)	Primary material of walls(Code3)	Primary material of roof (Code4)	Primary material of floor(Code4)	Toilet Facility (Code2)	Drainage/ Sewage (Code-2)	Major Source of Drinking Water (Code-5)
Code-1 : Owned=1, Rented=2, Other (Specify)=3. **Code-2** : Yes=1, No=2. **Code-3** : Mud=1, Bricks=2, Cement/Stone=3, Wood=4, Other (specify)=5. **Code-4** : Leaves/Bamboo=1, Mud=2, Concrete cement=3, Metal/asbestos=4, Tiles=5, other (specify)=6. **Code-5** : Open well=1, Hand pump=2, Public Stand Post=3, Tank/pond=4, Stream/canal/river=5, Overhead tank=6. Other(specify)=7								

8. **Production of Various Farm Output (kg) for Last Agriculture Year**

Crops	Variety	Area in Acers			Kharif Yield 2016-17	Rabi Yield 2016-17	Summer Crop 2016-17	Total Quantity	Value of output	Reasons for Variety
		Wet	Dry	Total						
Paddy										
Gandagashala										
Rubber										
Tea										
Coffee										
Coconut										
Ginger										
Pepper										
Areca nut										
Banana										
Cardamom										
Coco										
Tapioca										
Turmeric										
Vegetables										
Other crops										
Specify										

Value of the grass: from paddy Rs………………………..
Values of residual from other crops: Rs……………

9. Cost of Cultivation: Operational Costs per Acre

Cost of Cultivation: Operational Costs Per Acre			
Operation	**Summer Paddy**	**Autumn Paddy**	**Spring Paddy**

	Casual rate	Piece rate	Casual rate	Piece rate	Casual rate	Piece rate
Tractor Ploughing						
Bullock Ploughing						
Total paid out Material Cost						
Manure Cost						
Seed Cost						
Fertilizer Cost						
Pesticide Costs						
Harvester costs						
Transport costs						
Fixed costs						
Total Costs						
Operation	**Rubber**		**Tea**		**Coconut**	
Tractor Ploughing						
Bullock Ploughing						
Total paid out Material Cost						
Manure Cost						
Seed Cost						
Fertilizer Cost						
Pesticide Costs						
Harvester costs						
Transport costs						
Fixed costs						
Total Costs						
Operation	**Ginger**		**Pepper**		**Arecanuts**	
Tractor Ploughing						
Bullock Ploughing						
Total paid out Material Cost						
Manure Cost						
Seed Cost						
Fertilizer Cost						
Pesticide Costs#						
Harvester costs						
S						
Fixed costs*						
Total Costs						

Operation	**Banana**		**Coffee**		**Cardamom**	
Tractor Ploughing						
Bullock Ploughing						

Total paid out Material Cost						
Manure Cost						
Seed Cost						
Fertilizer Cost						
Pesticide Costs						
Harvester costs						
Transport costs						
Fixed costs						
Total Costs						
Operation	**Tapioca**		**Vegetables**		**Turmeric**	
Tractor Ploughing						
Bullock Ploughing						
Total paid out Material Cost						
Manure Cost						
Seed Cost						
Fertilizer Cost						
Pesticide Costs#						
Harvester costs						
Transport costs						
Fixed costs*						
Total Costs						

Fixed Costs: Motor …………….Sprayer ………………….Pump ………………. Tractor……………………Harvester……………………Ploughs…………..

10. Sources of Irrigation

Sources	If yes use code 1	If no use code 2	Extraction means (Code 1)	Electricity costs
Canal				
Own pump/Bore/Boring Tube well				
Pond				
River				
Water Tank				
Govt. Tube Well				
Public Well				
Sprinkle Irrigation				
Any other Streams				

Code 1= Manual, 2=Using Electricity.

11. What do you think reasons for labour shortage?

Reasons	Whether exist? 1 = Yes |___| 2 = No |___|

The availability of other local jobs with higher wage	
The emergence of MGNREGS	
Seasonal nature of agriculture jobs	
The transition to a full-time job	
Perception of agriculture occupation as low esteem	
Migraion to other cities	
Higher educational attainment and occupational mobility	
International migration	

12. Agricultural diversification within households

Buffalos	**No:**	**Cost:**	**Litters**	**Duration**	**Home consumption of milk**
Milk sold	**Chicken No**	**Chicken Sold**	**Fishing**	**Vegetables**	**Non paddy crop 1= if yes 22 of no**

13. Credit: Institutional

Agency	**Outstanding loan**	**Rate of interest**	**Collateral Code 1**
Cooperative			
RRBs			
Commercial bank			
Code 1: 1= Land, 2=house , 3= gold , 4=crop output , 5 = other Specify			

14. Non institutional Sources of Credit

Agency	**Outstanding loan**	**Rate of interest**	**Collateral Code 1**
SHGs /JLG/Kudembashree			
Money lenders			
Traders			
Land lords			
Relatives			
Friends			
Code 1: 1= Land, 2=house , 3= gold , 4=crop output , 5 = other Specify			

15. Data for Technical Efficiency of Farms

Education level		Access to loan	
Household size		Off-farm income	
Gender		Farm size	
Age		Distance to market for agricultural input	
Farm income from livestock ownership		Distance to market for marketing agricultural output	
Extension contact		Temperature	
Awareness about Climate change		Rainfall	
Framing Experience		Use of modern technology	

16 Perception of Climate Change

16.1 Do you think whether climate changing is happening? 1 = Yes |___| 2 = No |___|

16.2 If yes, can you rank climate change related incident occurring here?

Sl no	Climate change factors	Assigned rank
1	Higher average Temperature	
2	Excess Rain	
3	Incidents of droughts	
4	Incidence of Flood	
5	Decline in Rainfall	
6	Delay in rainfall	
7	Growing Season Changes	
8	Extreme Weather events	
9	Forest Fire	
10	Land Slide	

16.3 Whether Climate change affect your farms 1 = Yes |___| 2 = No |___|

16.4 What you think about how climate change affects your farms?

17 Adaptation strategies used by farmers

Adaptation option	**Do you adopt this method**	
Change in Cropping Patten	1 = Yes |___|	2 = No |___|
Application of lift irrigation method	1 = Yes |___|	2 = No |___|
Mixed farming	1 = Yes |___|	2 = No |___|
Altering cropping pattern towards growing less water- intensive or rained crops	1 = Yes |___|	2 = No |___|
Construction of farm ponds	1 = Yes |___|	2 = No |___|
Livelihood diversification through increase in non-farm employment	1 = Yes |___|	2 = No |___|
Increase in number of livestock particularly milch animals and goats	1 = Yes |___|	2 = No |___|
Installation of new bore wells and wells	1 = Yes |___|	2 = No |___|
Shifting from crops to trees crops	1 = Yes |___|	2 = No |___|
Migration	1 = Yes |___|	2 = No |___|

18. Coping Strategies Adopted by Farmers

Sl no	**Coping Strategies**	**Do you adopt this method**
1	Adoption of drought tolerant verities	1 = Yes |___| 2 = No |___|
2	Application of drip irrigation method	1 = Yes |___| 2 = No |___|
3	Summer Ploughing	1 = Yes |___| 2 = No |___|
4	Direct Sowing	1 = Yes |___| 2 = No |___|
5	Transplanting	1 = Yes |___| 2 = No |___|
6	Continuous Cropping	1 = Yes |___| 2 = No |___|
7	Crop Insurance	1 = Yes |___| 2 = No |___|
8	Shifting from long to short duration varieties	1 = Yes |___| 2 = No |___|
9	Increased irrigation facilities.	1 = Yes |___| 2 = No |___|
10	Delayed sowing	1 = Yes |___| 2 = No |___|

Date: **Contact number**

Place: **Name**

Time: **Signature of the respondent**

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Effects of Adaptation to Climate Change on Technical Efficiency of Paddy Farmers in Panamaram

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Abstract

Growing body of scientific literature published by the reports of the Intergovernmental Panel on Climate Change (IPCC) undoubtedly states that ongoing climate change is real and anthropogenic. Every sector of the economy will be adversely affected by ongoing climate change; however, immediate effects are being felt on agriculture sector as it is the man-made adjacent to the natural ecosystem. Although, mitigation and adaptation are the two-policy response to climate change, vulnerability of the agricultural system to climate change may be lessened to a large extent by increasing adaptation capacity of the agriculture to climate change. An attempt is made to understand efficiency effects of coping strategies and adaptation practices of Panamaram paddy farmers to climate change in Wayanad district of Kerala. Panamaram is one of the four Community Development Block of the Wayanad District of Kerala State of India, has largest concentration of production and area under paddy. Majority of the farmers are small and marginal and practices paddy cultivation only once in a year on their unirrigated plots. Technical efficiency of farmers coping and adapting to climate change is investigated using stochastic frontier production function approach. Based on random sample of 138 paddy farmers, study found that efficiency effects of adaptation strategy of the paddy farmers is more effective compared to copingstrategies. In response to different climatic anomaly, especiallyirregular rainfall pattern and incidents of flood, majority of the farmers resort to delay in sowing as an important coping strategy. Whereas farmers in long term end in view adopt changes in the cropping pattern as an important adaptation practice to climate change. Therefore, study suggest importance of adaptation practices and coping strategies to climate change in farm level planning.

Keywords. Climate change; Paddy cultivation; technical efficiency; stochastic frontier; climate change adaptation, coping strategies.

Introduction

The agricultural sector is at the heart of the economies of the less developed countries (FAO, 2002). However, the importance of this sector in context of less developed countries reveals decreasing contribution of agriculture to gross domestic product on one hand and increasing dependance of growing population in agriculture on the other(Annemarie, 2015). With reference to Indian economy, when more than 70 per cent rural households depend on agriculture and provides employment to over 60 percent, however, contribute only around 17 percent to gross domestic product (Narasimha et al, 2010).Moreover, recently central role of agriculture in the growth and development process has been challenged due to many reasons. There is policy, technological and environmental related fatigue which constraints agriculture to realizes its full potential.

Intergovernmental Panel on Climate Change (IPCC) in its major assessment reports unequivocally document the presence of climate change. Major perceived realities with climate change include melting of polar and mountain ice caps, resultant sea level rise and drowning of coastal areas, irregular rainfall

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