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Impact of Climate Change on Paddy Cultivation in Kerala

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Article History

Abstract

This study investigates the impact of climate change on paddy cultivation in Kerala, focusing on yield and yield variability. Kerala's agriculture is heavily dependent on paddy cultivation, making it crucial to understand the implications of climate change on this sector. The study analyzes climate variability in Kerala, examining changes in temperature and rainfall patterns over the past decades and their effects on paddy yield. Using the Just and Pope production function, the research evaluates the relationship between climatic factors and paddy yield, incorporating both mean and variance regression models. Results indicate seasonal variations in rainfall and temperature, with specific seasons showing positive or negative impacts on paddy yield. For instance, winter and summer temperatures positively affect yield, while excessive rainfall during the autumn season negatively impacts productivity. The study highlights the increasing variability in rainfall during the southwest monsoon, posing a substantial risk to the agricultural economy. Moreover, the analysis shows that temperature and rainfall interaction play an important role in determining yield outcomes. The research highlights the importance of adopting climate-resilient practices to combat the adverse effects of climate change. These practices include conservation agriculture and developing paddy varieties that can withstand higher temperatures. By assessing how climate variability impacts paddy cultivation, this study provides insights for both policymakers and farmers. It stresses the need for practical strategies to adapt to and mitigate climate change, ensuring food security and sustainable farming in Kerala.

Key Words; Climate change, paddy cultivation, yield variability
JEL: Q15, Q54 Q57, Q18, O13
UDC: 551.5 (551.58),

Introduction

Intergovernmental Panel on Climate Change (IPCC) in its major assessment reports assert that ongoing climate change is real and anthropogenic. Every sector of the economy will be affected by climate change, however, being a climate-dependent and sensitive, the agriculture sector will be most vulnerable. Changes in global average atmospheric and ocean temperature, local rainfall pattern changes, melting of polar ice caps and resultant sea level rise, drowning of the coastal area, shifting of local ecological zones and extreme climatic conditions such as drought and flood are some of the observed climate change impacts all over the world. Kerala has experienced a temperature rise, with an increase of 0.5°C in the last century (Ajithkumar et al.,2020). This warming trend is expected to continue, with projected increases of 2-3°C by 2050 (Dhanya et al., 2019). Changes in precipitation patterns have also been observed, with a decline in summer monsoon rainfall and an increase in winter rainfall (Kulkarni et al., 2020). Climate change led to increased frequency and severity of extreme weather events, such as floods and droughts, which have adverse impacts on agriculture (Saseendran et al., 2000). Warmer temperatures and changing precipitation patterns have also altered the growing conditions for crops, leading to reduced yields and increased variability (Ray et al., 2015). Additionally, climate change has increased the spread of pests and diseases, further reducing crop yields (Skendžić et al., 2021).

Research on climate change impacts on agriculture in Kerala has highlighted concerns regarding yield variability, particularly in the crop sector. Increased temperature and precipitation variability are expected to lead to more frequent and severe crop failures, affecting farmers' livelihoods (Vogel et al., 2019). Studies have reported that farmers in Kerala are already experiencing increased yield variability, with losses of up to 50% in recent years (Sabu et al., 2020). To mitigate these impacts, climate-resilient practices like conservation agriculture and agroforestry are recommended (Altieri et al., 2015). Specifically, for rice crops, limited studies have investigated climate change impacts in Kerala. However, research suggests that elevated CO2 and increased rainfall may offset the negative effects of temperature rise on rice production, potentially shortening maturity periods and increasing yields (Saseendran et al., 2000). Conversely, other studies predict decreased rice yields due to higher temperatures and reduced rainfall, emphasizing the need for adaptation measures like temperature-tolerant varieties and planting date shifts (Oort et al., 2017). Moreover, erratic rainfall patterns have led to declines in autumn rice cultivation, highlighting the strong correlation between production, productivity, and rainfall in June and July (Sabu et al 2020).

This study aims to contribute to the existing body of research on climate change impacts on agriculture in Kerala, with a specific focus on paddy production. Based on secondary data sources, the present study seeks to understand the impact of climate change on yield and yield variability in paddy production in Kerala. The study has two specific objectives. Firstly, to analyze climate variability in the study area, and secondly, to investigate the impact of climate change on yield and yield variability in paddy production in Kerala. The subsequent sections of this study are organized accordingly, with the first part providing an analysis of climate variability in the study area, followed by an examination of the impact of climate change on yield and yield variability in paddy production in Kerala.

Materials and Methods

This study uses datasets and analytical methods to investigate the impact of climate change on paddy cultivation in Kerala. Rainfall and temperature data were collected from the Indian Meteorological Department (IMD), which supplies comprehensive and reliable climatic variables. Regional specific climate data for Wayanad and Palakkad is extracted from NASA, Data Access Vie. Data on paddy production, including area and yield, were obtained from the Agricultural Statistics of the Government of Kerala and the Directorate of Economics and Statistics (DSE). Disaster management reports and other government publications were used to understand the context of climatic impacts. Journal articles were also reviewed to support the analysis and interpretation of results. The Just and Pope production function was used to assess the effect of climatic factors on paddy yield and its variability. This stochastic production function accounts for both the mean and variance of crop yield, offering a framework for examining the influence of climate change variables. The function was specified to include variables such as the area under paddy cultivation, season-wise average rainfall and temperature, and the standard deviation of rainfall for each season. Interaction terms between rainfall and temperature were also incorporated to capture their combined effect on yield. The analysis covered 30 years from 1990 to 2020, allowing for an assessment of long-term trends and patterns.

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

$y = f(X, \beta) + h(X, \alpha)\varepsilon$………. (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

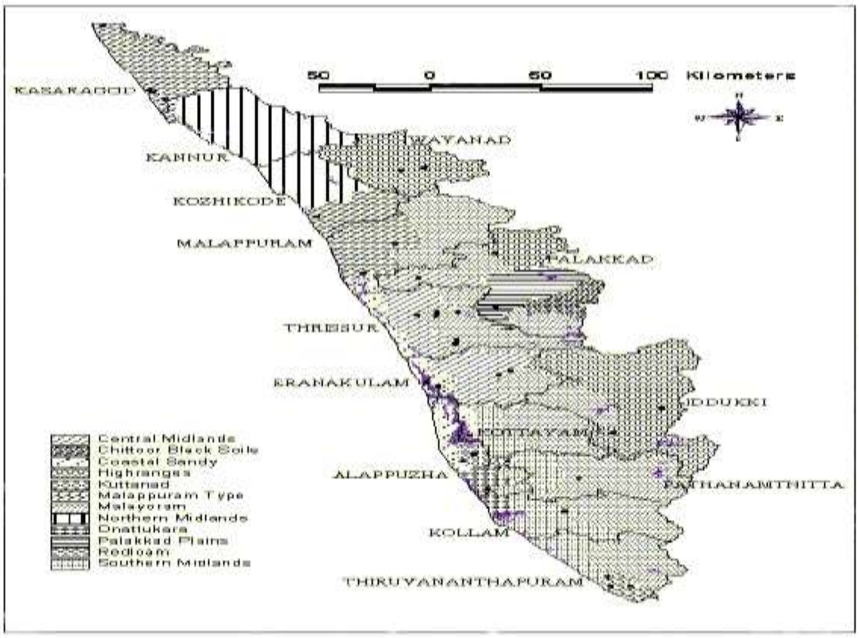
$$Pyield_t = \beta_0 + \alpha_i + \beta_1 Parea_t + \beta_2 SRain_t + \beta_3 StdevRain_t + \beta_5 STemp_t + \beta_6 STemp.SRain_t + \beta_7 trend_t + h(X, \alpha_i)\varepsilon \text{ ....(2)}$$

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.

Study area.

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

Agro Climatic Zones of Kerala



Source: Adapted from Kerala Agriculture University: 2002

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 (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.

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 (Walia et al., 2020). The temporal distribution of Natural disasters in Kerala since 1970 is given in the table 1. 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 1, 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.

Kerala, being most vulnerable to climate change (KSAPCC, 2007, 2014, 2021), presents a context for investigating the impacts of climate variability on paddy cultivation. Wayanad and Palakkad districts are identified as important paddy-producing regions within Kerala, this study focuses on these areas to understand the region-specific effects of climate change on paddy cultivation.

Climate Variability of the Study Area

Kerala got around 68 % of annual rainfall from South west monsoon season between 1989-2018 (IMD, 2020). It is clear from below figure 1, 2 and table 2, that monthly, seasonal and annual rainfall does not show any significant increasing trend. June and July monthly

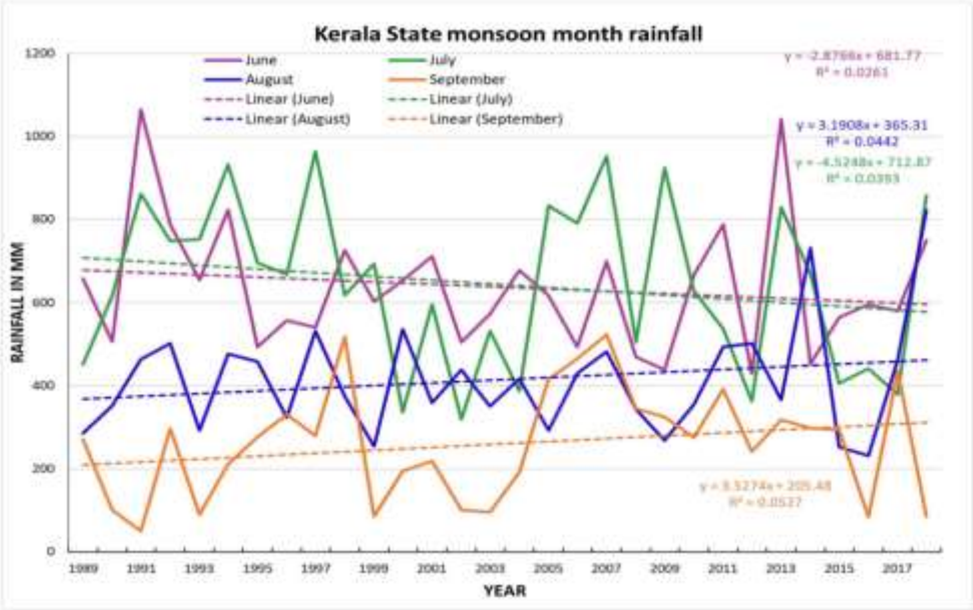
Table 2, Status of Annual and South-west Monsoon Season Rainfall (mm) for 1989-2018.

	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

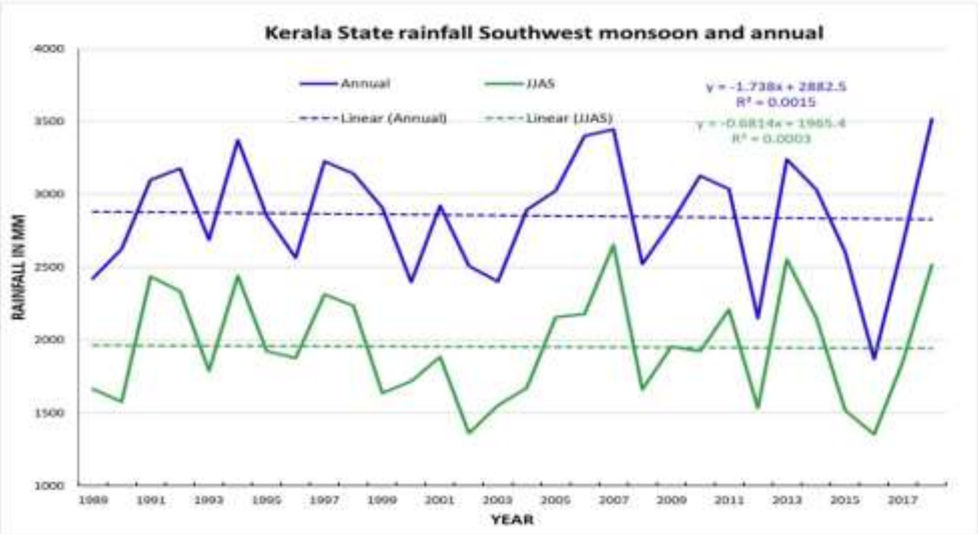
rainfall trends shows decreasing trend whereas August and September months rainfall shows a increasing trend. The variability of South-west monsoon rainfall between June to September is increasing, it poses a significant risk to the agricultural economy of the Kerala state since it is the important crop 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 increasing trend.

Figure 1, Trend in Monsoon Months Rainfall (mm) in Kerala



Source: Indian Meteorological Dept, 2020.

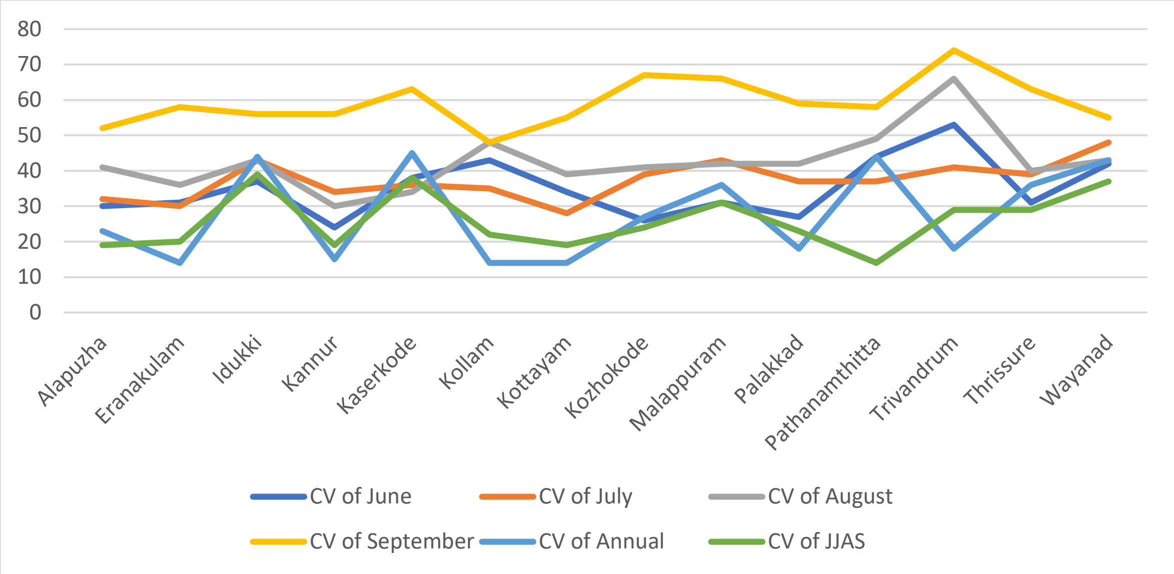
Figure 2, Trend in Southwest Monsoon Rainfall(mm) in Kerala



Source: Indian Meteorological Dept, 2020.

The figure 4 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.

Figure 3, South West Rainfall Variability at the District Level During 1989-2018



Source: Indian Meteorological Department, Trivandrum, 2020

Climatic Variability in the Palakkad and Wayanad

The table 3. 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.

Impact of Climate Change on Paddy Yield and its Variability.

According to Rosenzweig and Parry (1994) and Reilly et al. (1995), climate change in most developing countries is likely to be harmful and can reduce agricultural productivity. Knox et al. (2012) 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., 2001).

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 reasons in much of the literature on this topic. See, for instance, a few such studies are + (1996, 2011); Varkey (2004) Nikhil et al. (2009); Sheeba et al. (2019); 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.

Table 3, 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 V

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, 1993, 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 in Kerala fall under the coastal region in the west (low altitude), 13 districts in Kerala fall under the middle land region between the west and east (mid-altitude), and 13 districts in Kerala fall under the mountainous and high range area (high altitude). Because ten districts out of fourteen district in Kerala fall into three altitude regions, district altitude classification of climate sensitivity is difficult.

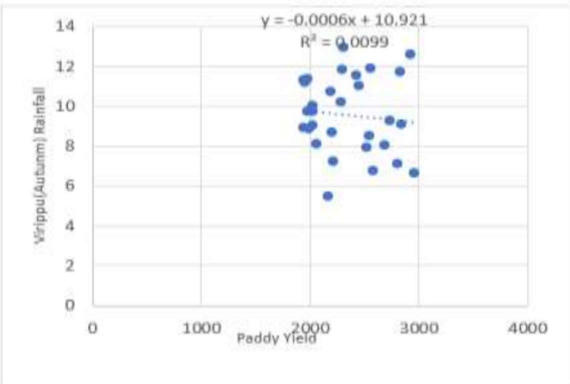
Relationship between Seasonal Rainfall and Paddy Yield

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 (b) and (c) Rainfall during the summer is critical for sowing and transplanting autumn (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 winter paddy (Mundakan paddy). However, as figure 4 (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.

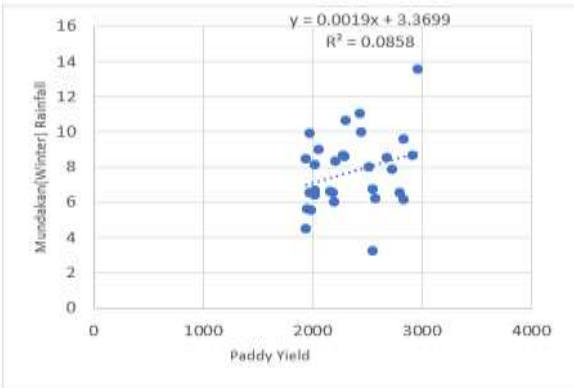
On the other hand, it has been observed from the figure 5. that, the temperature during all seasons had a positive effect on the yield of paddy. Seasonal minimum temperature and paddy yield show a positive relationship, whereas except for virippu paddy season, seasonal maximum temperature and paddy yield shows a positive relationship (figure 4). This kind of temperature is helpful for the increase in paddy yield as it leads to a better developmental stage through photosynthesis.

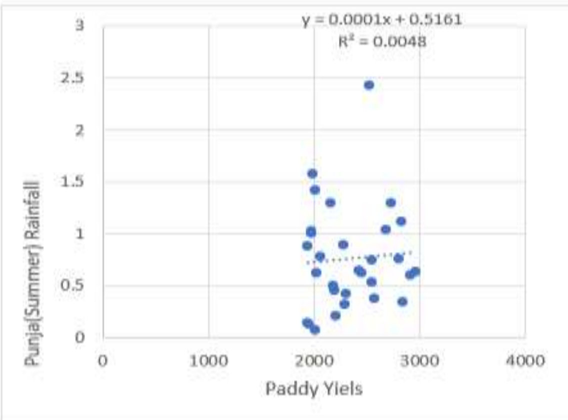
Figure 4, Relation between Rainfall and Paddy Yield

(a)



(b)





(c)

Figures 5, Relation between Seasonal Temperature and Paddy Yield

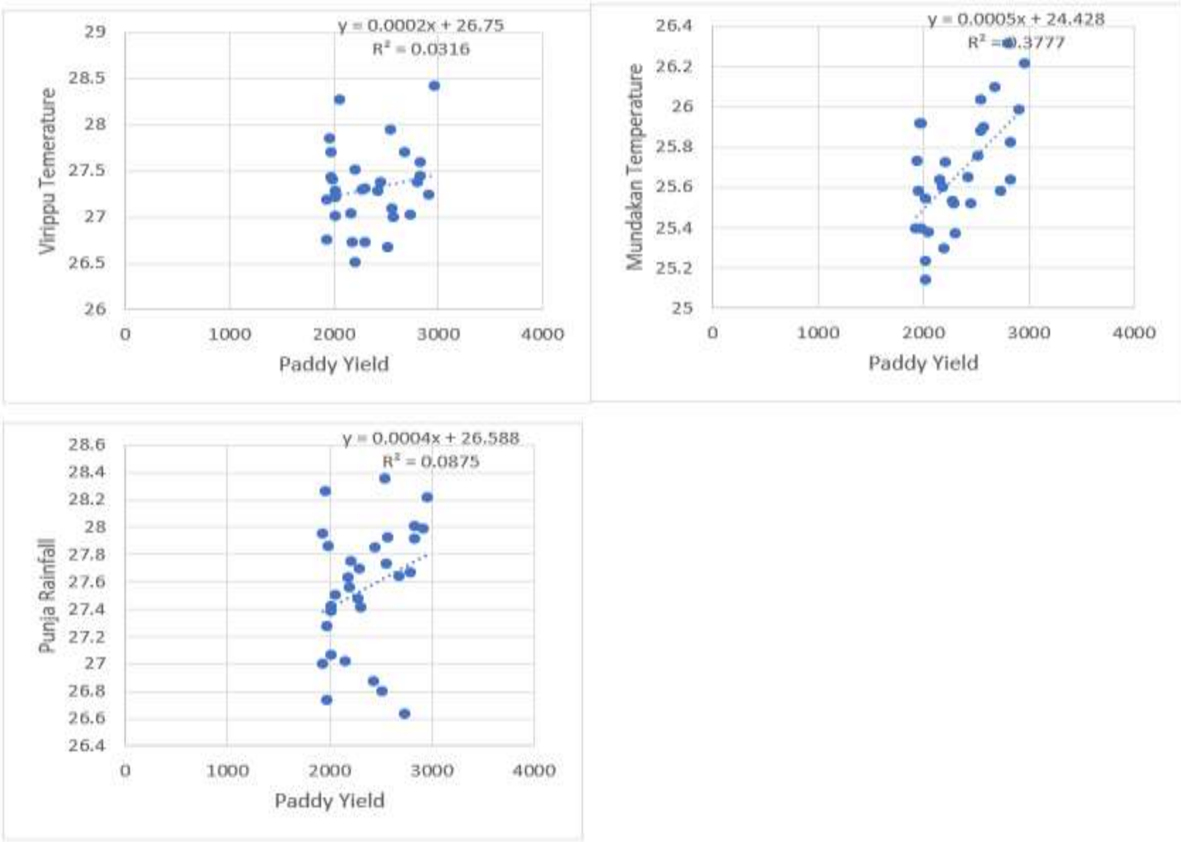
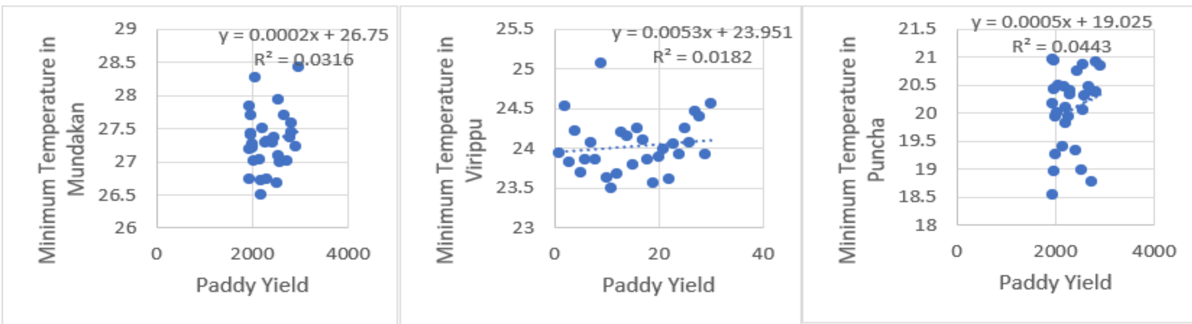


Figure 6, Relation Between Minimum and Maximum Temperature and Paddy Yield

Seasonal Minimum Temperature and Paddy Yield



Seasonal Maximum Temperature and Paddy Yield

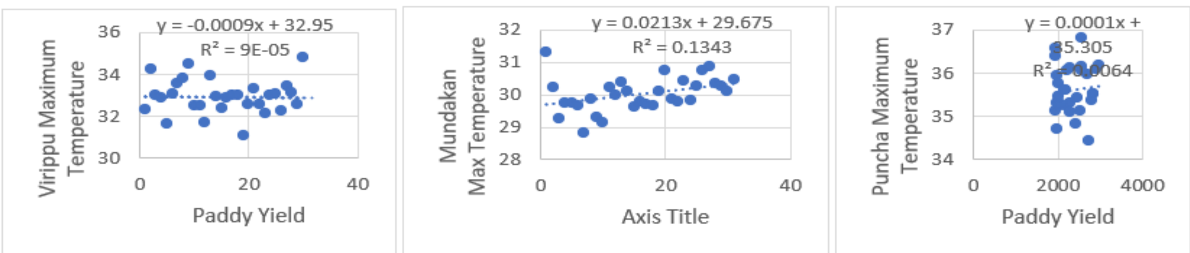


Table: 4 Estimated Result of the Mean and Variance Regression Model.

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 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 negative 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.

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