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Assessing the Impact of Climate Change on Agriculture: Farm-Level Evidence from Karnataka, India

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Abstract This study examines the impact of climate change on agriculture and explores the role of technology in its adaptation. For this purpose, primary data are collected from ecologically sensitive coastal and western ghat regions in the state of Karnataka. The study applied the Ricardian approach to estimate the climate sensitivity of agriculture in the region. A structured questionnaire with 98 questions collected various information from farmer households. Farmers' responses to these questions are presented as frequency tables and cross-sectional regression is applied under the Ricardian approach. The empirical results of the study confirm that farmers are aware of the sensitivity of agriculture to climate change. However, there is a lack of understanding of the adaptation of agriculture to climate change. Most farmers feel that since farming largely relies on nature, it is impossible to adapt to climate vagaries. Therefore, there is a greater need to educate farmers on possible adaptation strategies. Further, there is no greater variation in the crops cultivated and farmers' responses across different districts in the study area. There is a lot of scope for using technology to educate farmers on climate risks and possible adaptation strategies. Results of the Ricardian model reveal that erratic rainfall has a negative impact on farmland value. Among the socioeconomic variables, land belonging to socially backward communities commands less value than forward communities. Variables like education and households practising agriculture as the main profession positively influenced farmland values. Based on findings, several policy implications are highlighted, with the prominent being helping farmers diversify earnings, and communicating the standard adaptation strategies using cost-effective communications with greater reach.

Keywords Ricardian Approach, Climate Change, Adaptation

JEL Classification: Q12, Q15, Q54

1. Introduction

Global climate change has become a buzzword in policy circles more seriously than ever. The Intergovernmental Panel on Climate Change (IPCC) report ‘Climate Change 2013: The Physical Science Basis’ in its summary for policymakers, has articulated the global climate change as a process of increase in the atmosphere and sea temperature, decline in the amount of snow, rise in the sea level and increase in the emission of greenhouse gases. Climate change is significant because it is primarily induced by human action. Especially over the past century, a large amount of carbon dioxide and other greenhouse gases have been emitted into the atmosphere by burning fossil fuels and industrial expansion. Deforestation due to large-scale economic activities, in turn, has accentuated the process of climate change.

Climate change can have an impact on society and ecosystems in many ways. It can affect patterns of rainfall, agriculture production and productivity. Climate change can also affect human health and cause changes in the planet's ecosystem. It can pose severe challenges to countries' desire for sustainable economic development.

Governments at the national and regional/ local levels, international organisations, and local non-governmental organisations plan to adapt to the anticipated changes.

The growing literature on climate change and its impact on agriculture has found several facts. First, the agricultural sector is vulnerable to climate change both in physical and economic terms. It affects the supply of agricultural commodities and reallocates the resources within the sector due to changes in the relative prices of products. Second, although climate change is a global phenomenon, the impact on agriculture is not uniform. The studies conducted mainly in developed countries indicate that the adverse effects of climate change on agriculture are much less in developed countries than in developing ones. This is mainly because the socio-economic background of agriculture is much different in developed and developing regions. However, there needs to be more research in developing countries.

Houghton [1] has identified the three main channels through which climate change affects agriculture. First, moisture in the soil is affected by the changing temperature and precipitation levels. The availability of irrigation facilities can help to mitigate this problem. However, the availability of irrigation is heavily dependent on climate change. Second, crop yields are affected by changes in temperature. However, the impact will depend on the optimum tolerance of different crops. So, the effect will be more pronounced in crops close to the maximum tolerance limits under present conditions. Third, changes in the geographical range of pests and diseases may affect the agricultural productivity in a region.

2. Indian Scenario

The Ministry of Environment & Forests, Government of India's report titled “Climate Change and India: A 4X4 Assessment. A sectoral and regional analysis for 2030s” (henceforth MEF Report) documented the observed climate changes in India. Based on the data maintained by the Indian Meteorological Department (IMD) across more than 500 stations for over a century, the report has made the following observations. First, the annual mean temperature in India has shown a significant upward trend of 0.51 ℃ per 100 years during the 1901- 2004 period. The mean temperature increased by 0.2 ℃ per decade during 1971- 2007. Second, the all-India mean annual maximum temperature also has shown an increase of 0.71 ℃ per 100 years. Third, the all-India mean annual minimum temperature increased by 0.2 ℃ during 1991- 2007. This is mainly attributed to the rise in the pre-monsoon and monsoon temperatures. Fourth, in terms of extreme temperature events, occurrences of hot days are showing an increasing trend, and cold days are a declining trend. Fifth, the Indian monsoon shows a well-defined variability in block periods, with each block period of nearly three decades. From 1871 to 1920, deficient years were more than excess years; from 1921 to 1960, excess years were more than deficient. From 1961 to 2009, deficient years were more than excess years. However, there is an increase in the occurrence of extreme rainfall events and their intensity during this period.

The MEF Report has indicated several projections of climate change for India. The precipitation projections indicate a 3% to 7% overall increase in all India’s summer monsoon rainfall in the 2030s concerning the 1970s. Simulations for the 2030s show an all-round warming over the Indian subcontinent associated with increasing greenhouse gas concentrations. The seasons may be warmer by around 2 ℃ towards the 2030s. The analysis of the three model simulations indicates that both the daily extremes in surface air temperature may intensify in the 2030s with climate change; it is projected that the sea level may rise further than what it is today and with the warming of the oceans; the intensity and frequency of cyclonic activities and storm surges may increase.

3. Objectives of the Study

Given the overwhelming evidence of climate change’s impact on agriculture and the significance of agriculture to the Indian economy, the study aims to investigate the economic impact of climate change on agriculture in the selected regions. It is also to be noted that there are very few studies in the Indian context, especially examining the impact at the farm level. Therefore, the study states the following objectives:

1) To examine the economic impact of climate change on agriculture based on the Ricardian approach using farm-level data.
2) To examine farmers' awareness of the issues of climate change and adaptation strategies.
3) To examine the role of technology in adapting agriculture to climate change.

4. Review of Literature

There are two approaches to studying the economic impact of climate change on agriculture, viz., using the production function approach to estimate the climate change impact on various crops and the Ricardian model. In this section, we review a few studies on the economic effects of climate change using the Ricardian approach. Mendelsohn [2] examined the impact of global warming on agriculture in the US. Specifically, the study measured the effects of climate on land prices. The study has used cross-sectional data from about 3,000 counties in the US. The study measured the impact of climate and socioeconomic variables on farmland prices. The study found that temperature hurt farm prices in all seasons except autumn. Precipitation was found to have a positive impact on farmland prices outside autumn. The study observed that climate change impact on agriculture quantified based on the Ricardian approach is significantly lower than the production-based models. Contrary to popular perception, the study also documented a case of climate change helping agriculture.

Ericksen [3] examined the socioeconomic implications of climate change for Bangladesh mainly from the point of impact on the economy, society, and the country's vulnerability to future climate events. Climate changes are expected to impact natural resources like water, forests, and grassland. Loss of livelihood at the village level is expected to induce migration, and a linkage was seen between climate change and the health of the citizens. Fisher [4] has carried out a critical review of the Ricardian approach to measure the impact of climate change on agriculture in comparison with crop yield models. The authors agreed with the criticisms of the crop yield model's tendency to overestimate the effects of climate change on agriculture. However, they also pointed out that the Ricardian approach works better if the markets are competitive.

In the Indian context, Kumar [5] has applied the Ricardian approach to estimate the sensitivity of Indian agriculture to climate change. Farm net revenues at the district level were regressed on climate and socioeconomic variables. The study has captured the impact on the marketed agricultural output and completely ignored the non-marketed farm output. Mendelsohn [6] observed that present-day developing countries are very vulnerable to climate change as these countries heavily depend on agriculture. They argued that the prediction of higher temperatures leads to a reduction in the farm yields as per the agronomic simulation models; such studies have not considered the possible adaptation that farmers may make to protect their interests. The empirical evidence from India and Brazil showed the resilience of farmers who took into account the local climate and were able to mitigate the impact of global warming.

Frederick [7] examined the socioeconomic impact of climate change concerning flood, drought, and water shortage in the case of the US. The study has used several climate scenarios to examine the same. The study observed that greenhouse-induced warming is expected to intensify the costs of flood, drought, and water shortage across the US. However, the impact is going to vary substantially from one region to another region within the US. The study also documents opportunities available to mitigate the effects of climate change by adapting to climate change suitably. Smit [8] assessed various climate change adaptation strategies in the Canadian context. They classified them under four categories, viz. technological developments, government programs and insurance, farm production practices, and farm financial management. Along with these direct adaptation strategies, the study identified information provision as a potential adaptation strategy.

In the global context, Parry [9] examined the impact of climate change on crop yield, production, and risk of hunger under different climate scenarios. The study documented that a significant increase in the global temperature leads to a substantial decline in local and global crop yields. Though the worldwide crop yields did not change much under certain scenarios, the regional differences were great and could lead to the risk of hunger in poorer countries. O'Brien [10] examined the methodology to study regional climate vulnerability from multiple stress points of view, which are both local and global factors. The authors argued that the study's method would help assess the relative distribution of vulnerability to different stress points at local and regional levels. In this process, the study came up with locations that require interventions based on both regions and the themes under which it needs the intervention.

In South Africa, Gbetibouo [11] analysed the impact of climate change on field crops using the Ricardian approach. The study has estimated regression with farm-level net revenue as the dependent variable and climate-related variables, soil, and socioeconomic variables as explanatory variables. The results revealed that the studied crops were very sensitive to climate change in the form of temperature changes, whereas they were less sensitive to changes in precipitation. An increase in temperature led to increased farm revenue, whereas a reduction in rainfall reduced farm revenue. The study highlighted the need for localised adaptation strategies for climate change. Kurukulasuriya [12] examined the impact of climate change on agriculture by surveying 9000 farmers in 11 African countries. The study has used the Ricardian approach on the cross-sectional data of net farm revenue as the dependent variable and climate, water flow, soil, and other economic variables as explanatory variables. The study found that the farm's net income positively relates to precipitation and temperature.

Maddison [13] used the Ricardian approach to study the impact of climate change on agriculture in 11 African countries. Assuming a perfect adaptation to predicted climate change, African agriculture was severely vulnerable to climate change with substantial variations across countries. For example, climate change is expected to result in a crop loss of 19.9 percent in Burkina Faso and 30.5 percent in Niger. However, countries like Ethiopia are expected to experience only a 1.3 percent fall, whereas South Africa has a 3 percent fall. The study observed that water supply is essential and is highly sensitive to climate change. Karetnikov [14] examined the economic impact of climate change on the Illinois economy. The study argued that climate change will cause more precipitation and temperature in Illinois. Specifically, in agriculture, there will be soil erosion and increasing demand for irrigation facilities to compensate for the depletion of water tables. Climate change is also expected to have an impact on human health as well.

Seo [15] developed a structural Ricardian model to measure the impact of climate change on the choice of farm type in African agriculture. The study indicated that temperature increases encouraged the farmers to undertake mixed farming instead of crop-only or livestock-only farming. With the temperature rise, the revenues from mixed farming have increased, whereas crop-only or livestock-only farming has reduced. Increased precipitation has encouraged farmers to move from irrigated to rain-fed crops. With the increase in precipitation, the revenues from rain-fed crops have increased, whereas irrigated farms have reduced. Seo [16] estimated the impact of climate change on South American agriculture after considering the adaptation using the Ricardian approach. Specifically, the study documented the effect of global warming on the land value of 2300 farms using different climate change scenarios. The study found that the land values decrease as temperature increases and rainfall increases, except for farms with irrigation. The study estimated that the farmers would lose 14 percent of their income by 2020, 20 percent by 2060 and 53 percent by 2100 under severe scenarios. However, farms will lose marginally if a mild case scenario is assumed. All farms are vulnerable to the impact of warming; however, the effect is severe on small farms.

Once again, in the Indian context, Guiteras [17] examined the vulnerability of agriculture to climate change based on over 40 years of data. The study has used the district-level data of over 200 districts and tried to estimate the impact of weather on agricultural output. The study has estimated a crop yield decline of 4.5 percent to nine percent. However, in the absence of climate change adaptation, the output reduction could be as high as 25 percent. Savage [18] examined the socioeconomic impact of climate change in Afghanistan. Though there is no long-recorded climate historical data for Afghanistan, the study relied on the data of neighbouring countries. The climate projections indicate significant warming of temperature across Afghanistan, and it is projected to have an impact on various socioeconomic variables. The implications for agriculture are considered to be very high, with crop failure due to water shortage being the most significant risk.

Kumar [19] examined the climate sensitivity of Indian agriculture using four decades of data. The study found an increasing climate sensitivity of Indian agriculture, especially in the eighties and the late nineties. The study documented the presence of positive spatial autocorrelation and argued that inter-farmer communication could be the possible reason for such dependence. Challinor [20] examined the adaptation strategies for mitigating crop failure due to climate change for wheat in China. Based on a simulation exercise, the study predicted an increasing crop failure due to extreme heat and water stress. An increase in the mean temperature increases the crop failure rate, with the maximum failure rate being greater than the mean.

Passel [21] examined the impact of climate change on agriculture in the European region using the Ricardian approach. The study has used matched data on climate, soil, and other socio-economic variables across 37612 individual farms. The study has found that warming would lead to eight percent to 13 percent loss per degree Celsius in Southern Europe, whereas, the results were mixed for the rest of Europe. The study observed that precipitation positively influences agriculture; a centiliter increase in precipitation leads to a 3 percent increase in crop production. Gichere [22] examined the impact of flood and drought on the loss of crops and livestock in the case of Kenya. The weather events could be either induced by climate change or any random climate event. The study found that the extent of the loss was more in the case of crops than livestock. Masud [23] investigated the climate change impact on rice cultivation in Malaysia. The study documented that a minimal increase in temperature increased net revenue in the primary season, whereas it decreased the net revenue in the off-season. In contrast, a minimal increase in rainfall decreased net revenue in the main season, whereas it increased net revenue in the off-season.

Using the Ricardian approach, Nyuor [24] examined the economic impact of climate change on crop production in Ghana. Results showed varying degrees of climate impact on agriculture for two crops examined in the study. The study suggested the need for appropriate adaptation strategies. Using temperature and rainfall, Mishra [25] analysed the impact of climate change impact on agriculture in Odisha, India. Based on panel regression evidence, the study observed that both present and future climate scenarios negatively impact fam net revenue.

From the point of view of climate variables used in the Ricardian analysis, Vaitkeviciute [26] examined the different climate variables used in assessing the climate change impact on agriculture. Most studies used either a four-season average of temperature and precipitation or degree days. However, some studies highlighted the importance of temperature outside the growing season.

Bahadoran [27] analysed the impact of climate change on wheat crops in Iran. The study observed an inverse U-shaped relationship between land rent and precipitation. Overall, climate change significantly negatively impacted wheat production in Iran. Oo [28] applied the Ricardian approach to assess the climate vulnerability of Myanmar agriculture. The study documented a non-linear relationship between temperature and precipitation with land revenue.

In a recent study in the Indian context, Kalli [29] studied the extent of farm income loss due to climate change in Karnataka, India. The study observed that the negative impact of climate change on income is more in their study compared with extant studies in the Indian context. One degree rise in average minimum temperature led to a 17-21 percent fall in revenue. Malik [30] examined the climate change impact on agriculture in India's Jammu, Kashmir and Ladakh regions. Using the Ricardian approach, the study observed that temperature negatively impacted agriculture, whereas literacy and credit facility positively impacted land values.

A few broad trends emerge from the review of the literature. For example, extant studies have relied on farm-level data or secondary data at region or district levels. The former category of studies has relied on cross-sectional regression techniques, whereas the latter used panel data or other techniques. Studies can be classified as those that documented the impact of climate change along with socioeconomic variables and those that attempted to predict the impact of future climate change on agriculture in the form of loss of production, income, and livelihood. Some studies attempted to study climate change's impact on food security and hunger. Almost all studies have found significant evidence of climate change negatively impacting agriculture.

There are very few studies on the impact of climate change on agriculture in the Indian context. However, these studies have primarily relied on district-level agriculture output data. Therefore, there is a compelling need to examine the impact of climate change on agriculture using farm-level output in major ecologically sensitive regions.

5. Nature and Source of Data

The study requires information on farmland value, climate variables and socio-economic variables. Therefore, the study used the survey method to collect farm-level data and socio-economic variables. Specifically, farm-level information on the crops cultivated, the value of land, and other information. Socio-economic variables, viz. size of the holding, availability of the credit, geographic area, education, employment, representation of social group, etc., are also collected in the survey. Climate variables are collected from the survey and corroborated with secondary sources.

The study intended to use a simple random sampling technique to select the respondents for the study. However, due to COVID-19 travel restrictions and hesitancy on the part of farmers to speak to a stranger travelling to multiple locations, simple random sampling could not be applied in its letter and spirit. Therefore, it can be called a combination of convenience and snowball sampling. Data are collected from two ecologically sensitive regions, viz. coastal and western ghat regions spread across Dakshina Kannada, Udupi and Shivamogga districts. The period of data collection is from January to May 2022.

6. Methodology

The study uses the Ricardian approach to analyse climate change's impact on agriculture. Though the production function approach is used in the extant literature, it fails to capture the economic impact of climate change compared to the Ricardian approach. For example, the production function approach establishes the relationship between physical quantities of output and the climate variables. Meanwhile, the Ricardian approach considers the economic value of output as captured by the land value. Further, the flexible regression modelling framework can consider various socioeconomic variables that can influence the relationship between climate change and agriculture. For example, an educated farmer will be better positioned to infer the implications of weather prediction than a less educated farmer. Therefore, the Ricardian approach is preferred over the production function approach. This approach assumes that the adverse impact of climate change on agriculture will reflect on agriculture land value, and as a result, land that is vulnerable to climate change will command less value and, as a result, a lower price in the market. It assumes that agricultural land value is the present value of all future cash flows. If agricultural land is adversely affected by climate change, it reduces future cash flows and increases the risk. It may be summarised in the following equation:

$$PW \ \ of \ \ Land_{it} = \sum \frac{Cash \ \ Flow_{it}}{1 + i^t}$$

In the above equation, PW of land is the present worth of the land, Cash Flow represents the revenue from the agriculture carried out on the land, and i stands for appropriate discount rate. If there is a loss to crops due to climate change, it will lead to lesser cash flow and smaller PW. On the other hand, if the crop risk increases due to climate change, it leads to a higher discount rate and smaller PW. Therefore, climate change can affect both the numerator and the denominator, resulting in a smaller PW in land value.

From the extant literature, it is observed that two broad types of methodologies are used in assessing the impact of climate change on agriculture. Mostly, the farm-level studies used a cross-sectional regression model. Since the present study collected data from a primary survey at the farm level, this study estimates a cross-sectional regression model, which is specified below:

$$\begin{aligned} Land \ \ Value_i = \ \ & \alpha_1 + \\ \beta_1 Caste \ \ Group \ \ Dummy_i & + \\ \beta_2 Main \ \ Occupation \ \ Dummy_i & + \\ \beta_3 Crop \ \ Damage \ \ Dummy_i & + \\ \beta_4 Loan \ \ Borrowing \ \ Dummy_i & + \\ \beta_5 Temperature \ \ Shift \ \ Dummy_i & + \\ \beta_6 Rainfall \ \ Shift \ \ Dummy_i & + \\ \beta_7 Availability \ \ of \ \ Irrigation \ \ Dummy_i & + \\ + \beta_8 \ Highest \ \ Adult \ \ Education_i + \ \ & \varepsilon_i \end{aligned} \qquad (1)$$

In the above equation, the dependent variable is the value of the land. The caste group dummy takes a value of 1 if the household belongs to the ‘general’ category and zero for backward and socially marginalised groups. Households practising agriculture as the main occupation takes the value 1 and 0 for the rest in the main occupation dummy. Similarly, past crop loss experience, availability of irrigation, and loan borrowing take value 1, otherwise 0. Highest adult education is a continuous variable used in the model. For climate-related variables, the study uses dummy variables in the form of a temperature shift dummy and rainfall shit dummy based on the responses collected from the survey. This sharply contrasts with the extant studies that have used average temperature, rainfall or degree days. Using dummy variables instead of actual rainfall and temperature stems from the field survey experience. For example, within a 50-meter radius, there were lands with the ability to grow one to three crops depending on elevation. Though temperature or rainfall doesn’t change in such small areas, the impact of climate on these lands was different. Extreme rainfall would damage three-crop land more than single-crop land, whereas, deficient rainfall would cause more damage to single-crop land than three-crop land. Therefore, the study decided to use a dummy variable to proxy for climate-related variables at the farm level.

7. Empirical Results

Since the study relied on primary surveys, there is rich information on various agriculture and socioeconomic variables. Therefore, the study presents detailed information on land holding, dependence on agriculture, availability of irrigation, crops cultivated and crop loss, crop insurance, farmers' perception of climate change and strategies adopted to combat it, assistance needed to face climate vagaries and effective sources of information on climate events. An aggregate district-level study would miss this information. Table 1 presents the ownership status of the land they are cultivating. It is found that all farmers own at least some agricultural land. A small fraction of farmers may have rented others’ land, but that is an addition to their land. Further, they were asked about the extent of ownership regarding acres of land owned. Nearly 38 percent of farmers owned less than two acres, and about 48 percent owned less than five acres but more than two. Only a tiny three per cent of farmers owned more than 10 acres. This shows that though farmers own land, the extent of ownership is less and may preclude them from adopting any mechanisation or modern agricultural practices. When it comes to the area of cultivation of the owned land, it is observed that farmers are not using the entire land for agriculture. Though 38 per cent of farmers own less than two acres of land, 45 per cent cultivate less than two acres. This trend is observed under two acres category, where cultivating farmers exceeds the number of farmers owning that much land. The Opposite is found in the higher land ownership categories. One of the most common reasons cited by farmers for cultivating less land than they own is climate vagaries. Further, the number of crops that they grow is also severely restricted by the same.

The vulnerability of farmers to climate change depends on the extent of their dependence of farmers on agriculture. Lack of diversified sources of earnings can put them under severe stress in the event of crop failure or reduced yield due to climate change. Farmers were asked about their dependence on agriculture and whether they have any non-agriculture source of income.

The results of the same is shown in Table 2. As seen in the table, nearly 80 percent of the farmers said that agriculture is their primary occupation, whereas 82 percent said they don’t have any non-agriculture source of income. As argued earlier, this puts the farmers at greater risk as they don’t have any non-agriculture source of income.

Table 1. Area of Land Owned and Cultivated

Area	Owned		Cultivated	
	Frequency	Per cent	Frequency	Per cent
Under 2 Acre	150	38.46%	176	45.13%
2.1 to 5 Acre	186	47.69%	176	45.13%
5.1 to 10 Acre	43	11.03%	32	8.21%
Over 10 Acres	11	2.82%	6	1.54%
Total	390	100%	390	100%

Table 2. Status of Dependence on Agriculture

Response	Agriculture Primary Occupation		Non-Agriculture Income	
	Frequency	Per cent	Frequency	Per cent
Yes	313	80.26%	72	18.46%
No	47	12.05%	318	81.54%
Can't Say	30	7.69%	0	0%
Total	390	100%	390	100%

Since most farmers said they don't have sufficient irrigation, farmers were asked to specify what per cent of their land has an irrigation facility. As seen in Table 3, nearly 36 percent of farmers said that under 60 percent of their land has irrigation facility, and about 57 percent said that under 80 percent has irrigation. Only about 5 percent of farmers said that 100 percent of land is under irrigation. Overall, it shows that irrigation status is decent in the three sample districts.

Table 3. Percent of Land Covered Under Irrigation

Response	Frequency	Per cent
Under 40%	5	2.07%
41% to 60%	87	36.10%
61% to 80%	138	57.26%
81% to 100%	11	4.56%
Total	241	100%

Farmers were asked about the number of crops, both seasonal and perennial, that they are cultivating. Table 4 presents the results of the same. Only about six per cent of farmers were cultivating only one crop. Nearly 40 percent of farmers grew two crops, 30 percent cultivated three crops and about 19 percent cultivated four crops. About three percent of farmers cultivated a maximum number of six crops. This shows that farmers are diversifying into multiple crops, and as a result, failure of one crop may be compensated by other crops.

Table 4. Number of Crops Cultivated

Number of Crops	Frequency	Per cent
1	22	5.64%
2	154	39.49%
3	117	30.00%
4	75	19.23%
5	10	2.56%
6	12	3.08%
Total	390	100%

Since climate change can lead to adverse climatic conditions, it may result in the loss of crops. Therefore, farmers were asked whether they suffered crop loss in the last five years; the results are presented in Table 5. Nearly 97 percent of farmers said that they experienced crop loss. Though all crop loss incidents may not be directly linked with climate change, farmers experienced crop loss.

Since an overwhelming majority of farmers said they experienced crop loss, they were asked to elaborate on the reasons for crop loss. Table 6 presents the results of the same. Crop loss may result from multiple causes, so farmers were given a chance to cite multiple responses to the same question. Outright floods and drought are not usually experienced in the study area, and as a result, only about three percent of farmers said they lost crops due to these reasons.

Table 5. Details of Farmers' Suffering Crop Loss

Response	Frequency	Per cent
Yes	373	97.14%
No	11	2.86%
Total	384	100%

Table 6. Reasons for Crop Loss

Reasons	Frequency	Per cent
Flood	11	2.82%
Drought	11	2.82%
Other Adverse Climate Conditions	146	37.44%
Pest Attack	283	72.56%
Destruction by Animals	294	75.38%
Lack of Irrigation Facility	228	58.46%
Lack of Electricity	36	9.23%

Destruction by animals and pest attacks were cited as reasons for crop loss by 75 and 73 per cent of farmers, respectively. Lack of irrigation facility is cited by about 58 percent of farmers, and other adverse climate conditions were cited by about 37 percent of farmers. About nine percent of farmers said that lack of electricity for irrigation is also a reason for crop loss.

Since many farmers experience crop loss, the study was curious to determine whether farmers insure their crops to protect themselves from financial loss. Table 7 provides information about the same. Nearly 27 percent of farmers said that they had availed the crop insurance in the recent past. However, about 73 of farmers said that they did not insure their crops. This is surprising considering that despite suffering crop loss, farmers are not insuring their crops.

Table 7. Details of Insuring Crops

Response	Frequency	Per cent
Yes	107	27.44%
No	283	72.56%
Total	390	100%

Not just the information on insuring crops, even the frequency of insuring the crop, was discussed with the farmers. The results of the same is reported in Table 8.

Only about 10 per cent of farmers said they always insure their crops, whereas about 34 percent said they insure sometimes. However, a majority, 57 percent of farmers, said that they don't know. This is surprising because the amount of premium is sizable, and farmers don't know whether they insure crops regularly or not.

Table 8. Frequency of Insuring Crops

Response	Frequency	Per cent
Always	28	9.93%
Sometimes	93	32.98%
Don't Know	161	57.09%
Total	282	100%

Since most farmers have not insured their crops, an attempt was made to understand the reasons. The results of the same are presented in Table 9. The prominent reasons quoted by farmers are not having enough money to pay the premium at about 37 percent, followed by a feeling among farmers that the crop insurance is not helpful for farmers at about 24 percent and premium being too expensive at about 23 percent. Lack of money to pay premium and premiums being perceived as expensive are very closely related to each other. About 13 percent of farmers said they are unaware of any crop insurance program.

Table 9. Reasons for Not Insuring the Crops

Reasons	Frequency	Per cent
Not aware of crop insurance scheme	45	13.47%
Inadequate money to pay the premium	125	37.43%
Premium is expensive	78	23.35%
Insurance is not helpful to farmers	81	24.25%
Never got the promised money	0	0.00%
Rules are too stringent	5	1.50%
Total	334	100%

To assess the awareness of farmers on the impact of climate change on agriculture, they were asked whether they believe climate change is impacting their agriculture. Table 10 presents the results of the same. About 95 percent of farmers said that climate change is affecting agriculture. About four percent felt they didn’t know adequately about the relationship. Only a tiny fraction of farmers did not think it impacted agriculture.

Table 10. Climate Change Impacting Agriculture

Response	Frequency	Per cent
Yes	369	94.62%
No	6	1.54%
Don't Know	15	3.85%
Total	390	100%

Farmers were asked about the nature of climate change's impact on agriculture, and Table 11 presents the result. Since there could be multiple impacts, farmers were allowed to choose multiple options, so the sum of percent exceeds 100. About 88 percent of farmers felt that there is a reduction in yield due to the impact of climate change, whereas, 44 percent felt that there is crop loss. Finally, about eight percent of farmers thought that they were forced to cultivate a smaller number of crops. E.g., land growing three crops a year (two paddy and one urad), is now being forced to produce only two crops due to lack of surface water for the third crop. Similarly, the fields used for two crops are reduced to just one crop.

Table 11. Nature of Climate Change Impact

Response	Frequency	Per cent
Reduced yield	342	87.69%
Crop loss	172	44.10%
Reduced crop number	31	7.95%

Since the majority of farmers are aware of climate change's impact on agriculture and also experienced crop loss, they were asked about their response to find a solution to the same. Table 12 presents the results of the same.

Table 12. Farmers’ Response to Climate Change

Response	Frequency	Per cent
Did not make any adjustments	107	27.44%
Adding irrigation	169	43.33%
Changing planting date	25	6.41%
Using different crop varieties	168	43.08%

As seen in the table, about 27 percent of farmers said that they did not make any adjustments to their routine of practising agriculture. About 43 percent each said that they had added irrigation and started using different crop varieties to mitigate the impact of climate change. About six percent of farmers said that they have changed the planting date to suit the onset of the monsoon to avoid any potential losses if there is a late arrival of monsoon.

Farmers were asked about the assistance needed to adapt agriculture to climate change, and Table 13 presents the results. The single largest assistance farmers mentioned is having climate-resistant crops, and for that purpose, there should be research in this field. Accurate climate prediction at 17 percent and effective dissemination of information at 13 percent were other assistance farmers cited. Nearly 25 percent of farmers said they don’t know what type of assistance is needed to adapt their agriculture to climate change.

Table 13. Assistance Needed for Adapting to Climate Change

Response	Frequency	Per cent
Accurate climate prediction	68	17.44%
Effective dissemination of the information	51	13.08%
Research in climate-resistant crops	212	54.36%
Don't Know	96	24.62%

Farmers were asked about effective sources of climate information, and the results are presented in Table 14. Since farmers use multiple sources of information, they were asked to specify multiple reasons if they wished to do so. Over 90 percent of farmers said that newspapers and television are the best sources to disseminate information, whereas 48 percent of farmers said that sending messages to mobile phones is the best way. Only a tiny 8 per cent of farmers felt that the internet is the best source of information. Internet not getting much support from farmers is understandable, considering that farmers mostly live in rural areas and there is poor connectivity. Further, the nature of the job is such that it is difficult to use the Internet.

Table 14. Effective Sources of Information on Climate

Response	Frequency	Per cent
News Paper	364	93.33%
Television	374	95.90%
Messages to mobile phones	186	47.69%
Internet	31	7.95%

Farmers were enquired about the market value of the agricultural land they own, and the results are presented in Table 15. An attempt is made to convince the farmers to give value to agricultural land rather than the commercial value if it is converted to commercial purposes. Still, there is some impact of commercial value in the figures given by the farmers. Per acre land value of less than Rs. 10 lakhs was quoted by about 50 percent of farmers and cumulative percent of farmers quoting a price below this is about 67 percent farmers. Below Rs. 25 lakhs and 50 lakhs are quoted by about 11 percent and 18 percent of farmers. Significant variation in the land price quoted by farmers is understandable, considering the influence of local supply and demand factors. It also indicates that there is an influence of the commercial value on agricultural land, which farmers quoted. The average per acre of land is Rs. 1765300 from the sample respondents. However, the average value masks the significant variation in the quoted price of land. This is a crucial input for using the Ricardian approach to measuring climate change's impact on agriculture, which is used in this study.

Table 15. Per Acre Land Value

Amount	Frequency	Per cent
Below 1 Lakh	5	1.35%
1.1 to 5 Lakhs	57	15.41%
5.1 to 10 Lakhs	186	50.27%
10.1 to 15 Lakhs	10	2.70%
15.1 to 25 Lakhs	42	11.35%
25.1 to 50 Lakhs	65	17.57%
50.1 to 85 Lakhs	5	1.35%
Total	370	100%

Note: Average per acre land price is Rs. 1765300

The results of the Ricardian approach to measuring the impact of climate change on agriculture are presented in Table 16. The dependent variable is per acre land value in Rupees, and a host of socioeconomic and climate-related variables as independent variables. The caste group dummy measures the impact of social strata on the dependent variable. In this case, a household belonging to 'general' takes the value of 1, whereas the rest of the groups take the value of 0. The coefficient of the dummy variable is positive and statistically significant. It shows that the land owned by the 'general' category commands more value, indicating more output in those lands. Land belonging to households practising agriculture as the main occupation has more value than households for whom it is not the main occupation. The negative and statistically significant crop damage dummy coefficient shows that land which experienced crop loss has less value.

Table 16. Results of Regression of Ricardian Approach to Climate Change Impact on Agriculture

Variable	Standardised Coefficient	t Statistic	Probability	VIF
Constant		3.731	.000	
Caste Group Dummy (General =1, Else= 0)	.374	6.627	.000	1.27
Main Occupation Dummy (Agriculture= 1, Else= 0)	.141	2.684	.011	1.52
Crop Damage Dummy (1= Yes, No =0)	-.110	-1.983	.053	1.13
Loan Borrowing (1= Yes, No= 0)	-.076	-1.593	.097	1.15
Temperature Shift Dummy (1= Yes, No= 0)	-.103	-1.473	.131	1.10
Rainfall Shift Dummy (1= Yes, No =0)	-.113	-1.911	.055	1.09
Availability of Irrigation Dummy (1= Yes, No= 0)	.084	1.001	.251	1.16
Highest adult education (Number of Years)	.305	3.159	.010	1.08
R square value for the regression is 0.417.				

The land of the households borrowing loans is less valuable than that of those who are not borrowing the loan. It may be interpreted that those who didn't borrow may have access to their finance and, therefore, are generating better income than farmers who are borrowing. Two crucial climate-related variables, the temperature shift dummy and rainfall shift dummy, both have negative coefficients. However, the temperature shift dummy coefficient is statistically insignificant, whereas the rainfall shift dummy is significant. Availability of irrigation is positively related to land value as expected but the coefficient is not statistically significant.

It shows that the farmland experiencing a shift in rainfall is commanding a lesser value as it could affect the output. The highest adult education in the form of years of education received by either male or female member coefficient is positive and statistically significant. It shows that farmland owned by households with more education command more value. Finally, the irrigation availability dummy and number of years in agriculture variables coefficient are also statistically insignificant. The R square value of the regression is 0.417.

8. Conclusions

Agriculture is going through a very tricky phase in the Indian context. Its contribution to GDP is continuously declining, but its contribution to livelihood and significance to society remains intact. In the recent past, farmers in India have faced many difficulties in carrying out their profession due to both market failure and climate vagaries. This study attempts to examine the impact of climate change on agriculture in a climate-sensitive region, viz., coastal and western ghat regions located in Karnataka. The study relies on primary data collected using a structured questionnaire, and statistical techniques are used to analyse the data. Mainly, the study uses a Ricardian approach to assess climate change's impact on agriculture.

Based on farm-level data from about 390 farming households, results reveal that the impact of climate change on agriculture is not uniform but conditioned by various other socioeconomic variables. There is a negative impact of erratic rainfall on agriculture, whereas temperature is not having a significant effect. There is less value for land belonging to socially backward groups. Lands of educated farmers and farmers practicing agriculture as their main occupation is higher. The study observes that farmers are aware of climate sensitivity in agriculture. Further, there is also ignorance on the part of farmers regarding adapting agriculture in times of climate sensitivity. There is a clear sign of resigning to the fact that since agriculture is sensitive to climate, it cannot be adapted in the face of such climate change. Therefore, there is an urgent need to educate farmers regarding the possible strategies to adapt agriculture. There is excellent scope for technology to play a role in this regard in the form of mass communication media and telecom-based SMS services. These low-cost services have greater reach and customisation.

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