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# A Farm-Level Exploration of the Factors Influencing Climate Change Adaptation Strategies among Rice Farmers in Kerala, India

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## Abstract

Based on primary data collected through a farm-level survey of 600 households of the major rice-producing districts in the identified agroclimatic zones of Kerala, India, the study employs a multivariate probit model to study the determinants of climate change adaptation strategies of rice farmers. The estimation of the correlation of error terms of selected climate adaptation strategies supports the suitability of multivariate probit model. The results of the model confirm that the farmers' choice of adaptation strategies is significantly affected by factors such as age, gender, level of education, farm size, credit access, reliance on climate information, and access to agricultural extension services. The study further emphasizes the role of institutional factors through government policies such as improving accessibility to affordable credit and provision of reliable climate information, along with effective extension services that enhance the capabilities of farmers enabling them to adopt better climate change adaptation strategies.

## Keywords

Climate change, agriculture, adaptation strategies, farm household, multivariate probit model.

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## Introduction

Climate change has become one of the pressing issues faced by the world today due to the alarming levels of its adverse impact on nature as well as socio-economic systems. The impact of climate change has been witnessed in sectors such as agriculture, fisheries, tourism, forestry, and energy (Rao et al., 2019; van Ruijven, 2019; Swami and Parthasarathy, 2020; Yalew, 2020; Shine, 2023). Globally, overall agricultural productivity has slowed down due to climate change, having significant repercussions on food security across the nations (Intergovernmental Panel on Climate Change [IPCC], 2023).

Adaptation to climate change is crucial to protect the livelihoods of those dependent on agriculture. However, perceiving climate change is considered a prerequisite to adaptation, which is followed by planning and decision-making process to adopt from the identified adaptation strategies (Patel et al., 2023). Furthermore, like the impact of climate change, the adaptation strategies of the farmers and their perceptions of climate change are also highly location-specific (Swaminathan and Kesavan, 2012; Reddy et al. 2022).

In India, variability in the climate parameters of monsoon and temperature pose the biggest challenge to agriculture and food security (Swaminathan and Kesavan, 2012; Swami and Parthasarathy, 2020). India's vulnerability to climate change is aggravated due to its relatively higher dependence on agriculture for livelihood (Rao et al., 2019) coupled with the high sensitivity of rice to climate change leading to declined production and productivity of rice in comparison to the growing rate of population (Swain and Thomas, 2010).

Kerala, the 'gateway of monsoon' to India, has witnessed an increase in the frequency of extreme climate events such as floods, landslides, decreased rainfall leading to drought-like situations, water scarcity, cyclones, and extreme changes in temperature in recent years. The floods and landslides of 2018 and 2019 were stark reminders of Kerala's increasing vulnerability to climate change which led to enormous crop and yield losses, adversely affecting the agriculture sector (Rajiv Gandhi Institute of Development Studies, 2018; Kerala State Planning Board, 2021).

### Rice cultivation and climate change

Rice (Oryza sativa) assumes large significance in developing regions of the world, more specifically in the Asian continent, where it has been the principal crop for over 2,000 years (Connor et al., 2023). The importance of rice crop in India, and the changing climatic conditions have garnered interest in the scientific and economic assessment of the impact of climate change on rice in India (see Auffhammer et al., 2012; Gupta et al., 2014; Varghese et al., 2020; Aswathi et al., 2022; Dhanya and Jayarajan, 2023; Joseph et al., 2023).

Rice is considered as the staple food of Kerala, and its cultivation assumes significance in the agricultural profile of Kerala. Paddy is cultivated across all the districts of Kerala as it is the principal crop that falls under the category of food grains in Kerala. It is cultivated in all three seasons across all districts of Kerala, except Wayanad where there is no autumn cultivation (Government of Kerala, 2022).

Recent studies in the context of rice cultivation in Kerala have highlighted the vulnerability of rice to climate change impacting its yield, and therefore, suggest the importance of suitable adaptation strategies to reduce the yield loss (Varghese et al., 2020; Aswathi et al., 2022; Dhanya and Jayarajan, 2023; Directorate of Environment and Climate Change, 2022). Foreseeing the adverse impact of climate change on rice production in Kerala, adopting viable strategies becomes a necessity (Swaminathan and Kesavan, 2012; Varghese et al., 2020).

The present study attempts to understand the determinants of the adaptation strategies adopted by farmers to cope with climate change. This would help in evolving policies by taking cognizance of the farm-level experience in enhancing the adaptive capacities of the farmers concerning the impending impact of climate change.

### Description of the study area

The geographical location of Kerala lies between 8°18' and 12°48’ N latitude and 74°52' and 77°22' E longitude, encompassing an area of 38,863 sq km (38,86,287 ha) in the southwestern part of India. Based on climate, geomorphology, land use, and soil variability, Kerala is delineated into five agroecological zones (AEZ) and twenty-three agroecological units (AEU) (Kerala Agricultural University, 2020). The five agroecological zones are Coastal Plains, Midland Laterites, Foot Hills, High Hills, and Palakkad Plains, while the twenty-three agroecological are delineated considering panchayats as the primary unit. The geographical diversity of Kerala implies diversity in climate across the State. The plains are characterised by a hot and humid climate, while the high ranges have a cool climate.

## Materials and methods

Adaptation strategies help minimise the exposure risk of farmers to climate change through a reduction in the marginal impact of climate change on productivity (Mulwa et al., 2017). When faced with adverse climate conditions, farmers may resort to more than one adaptation strategy to ameliorate the adverse impact rather than resort to a single strategy (Ojo and Baiyegunhi, 2018). From the farmer’s perspective, a particular climate adaptation strategy is adopted if the expected benefits of adopting a particular strategy are greater than not adopting the strategy.

### Multivariate Probit Model

Following Chib and Greenberg (1998) a multivariate model is formulated such that:

$$Y_{ij}^{*} = X'_{ij}\beta_j + \varepsilon_{ij} \quad j = 1, 2, \ldots, m \tag{1}$$

$$Y_{ij} = \begin{cases} 1 \; if \; Y_{ij}^{*} > 0 \\ 0 \; if \; Y_{ij}^{*} < 0 \end{cases} \tag{2}$$

Where, $Y_{ij}^{*}$ is the latent variable that captures the unobserved factors and the observed choices associated with ith farm household adapting to jth adaptation strategy. $Y_{ij}$ represents the binary dependent variables of different climate adaptation strategies used by the farm households, and $X_i$ represents the vector of explanatory variables consisting of observed farm characteristics, household characteristics, etc. $\beta_j$ is the vector of parameters to be estimated, and $\varepsilon_{ij}$ is the error term following the normal distribution. Here, the farm households choose to adopt a particular adaptation strategy if the expected output is greater than zero ($Y_{ij}^{*} > 0$) and do not adopt, if otherwise ($Y_{ij}^{*} < 0$).

Multivariate probit model allows for the correlation between unobserved disturbances and the relationship between alternative adaptation strategies. The correlation could arise from either substitutability (negative correlation) or complementarities (positive correlation) among the adaptation strategies adopted by the farm households, the failure to capture which may lead to biased and inefficient estimates (Bahinipati and Venkatachalam, 2015; Mulwa et al., 2017; Regmi et al., 2023). However, with the possibility of jointly adopting more than one adaptation strategy, εij jointly follows multivariate normal (MVN) distribution, where the conditional mean is zero and the variance is one; $\varepsilon_{ij} \sim N\,(0, \omega)$. The resulting covariance matrix is expressed as follows:

$$\omega = \begin{bmatrix} 1 & \rho_{12} & \cdots & \rho_{1m} \\ \rho_{21} & 1 & \cdots & \rho_{2m} \\ \vdots & \vdots & 1 & \vdots \\ \rho_{m1} & \rho_{m2} & \cdots & 1 \end{bmatrix}, \qquad (3)$$

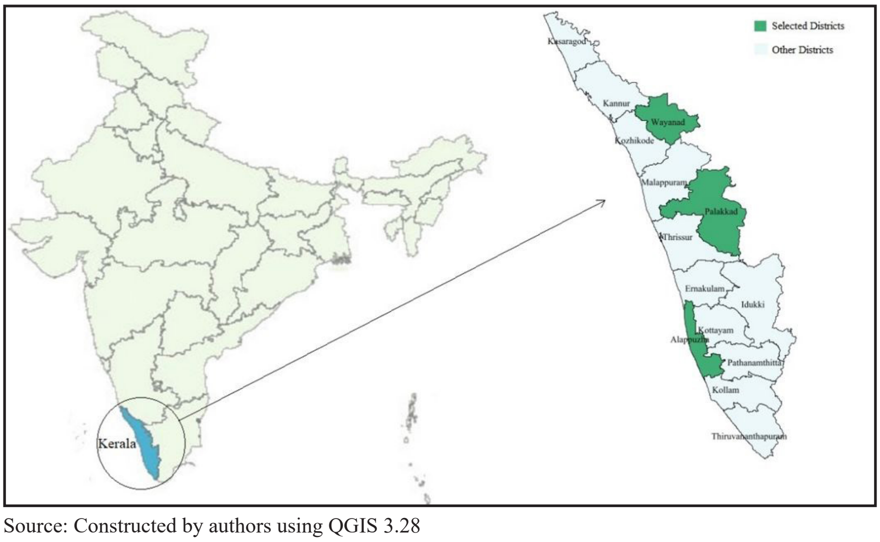
where, $\rho$ denotes the unobserved correlation between the stochastic components of the error terms with regard to any two of the adoption equations estimated in the model. The off-diagonal elements represent the correlation between the stochastic components of different adaptation strategies. If the correlation of error terms in the off-diagonal elements are non-zero, then Equation 1 becomes a multivariate model indicating joint adoption of adaptation strategies. The study uses Stata 17 software to analyse the data.

## Sampling and data collection

Primary data for the study was collected through questionnaires and focus group discussions (FGDs). The household survey questionnaire was designed to collect both qualitative and quantitative information regarding the socio-economic and demographic characteristics of households, farm characteristics, farmers' perceptions of climate change and their adaptation practices. Since the study relies on cross-sectional data collected through a survey of household farms in selected districts of Kerala, a multistage sampling method was deployed to select the sample households.

At first, out of the five agro-ecological zones of Kerala, the zones of Coastal Plain, Palakkad Plain and the High Hills were identified based on higher rice production and vulnerability to climate change, from which the major rice-producing districts of Alappuzha, Palakkad, and Wayanad respectively were selected (see Figure 1).

Kuttanad region of Alappuzha district being site designated under the Ramsar Convention, assumes international importance. The system of agriculture in Kuttanad is unique as the cultivation of rice is done below sea level in Kayals which are wetland rice fields created by pumping out water. Palakkad is known as the 'Rice bowl of Kerala' having the largest area of rice cultivation in Kerala. Wayanad district is identified as an ecologically sensitive area falling under the Western Ghats which is a geomorphic feature of immense global importance according to the UNESCO World Heritage Convention. While Palakkad and Alappuzha districts are the largest producers of rice in Kerala, Wayanad is known for the cultivation of numerous traditional varieties of paddy (see Rasheed et al., 2021a). After




Source: Constructed by authors using QGIS 3.28

Figure 1: Map of the study area.

randomly selecting the blocks of the three districts, panchayats to be surveyed from each district were selected. The details of padasekhara samithis (farmer organisations) were collected from Krishi Bhavans or agricultural offices to select the farm households to be surveyed. Padasekhara samithis were the points of contact for the interaction and discussion with farmers for the collection of data. Padasekhara samithis were also contacted to conduct focus group discussions (FGDs).

The sample size was calculated using Raosoft sample size calculator in which the sample size *n* and margin of error *E* are presented as:

$$x = Z(\frac{c}{100})^2 \times r(100 - r) \quad (4)$$

$$n = N\,x\,/((N - 1)E^2 + x) \quad (5)$$

$$E = \sqrt{[(N - n)x/n(N - 1)]} \quad (6)$$

where, $N$ signifies the population size, $r$ is the fraction of responses that the researcher is interested in, and $Z(c/100)$ is the critical value for the confidence level $c$. Applying this formula, the sample size of 200 farm households from each agro-climatic region was arrived at, aggregating to a total sample size of 600 farm households.

## Description of variables

Both the dependent and independent variables used in this study were identified based on the empirical literature, discussions with the farm households and the availability of data.

### Dependent variables

Adaptation strategies found in the literature and information obtained through the FGDs were used to arrive at the adaptation strategies practiced in the study area. The dependent variables used in the empirical estimation of this study constitute the adaptation strategies adopted by the farmers. The dependent variable of each adaptation strategy used in the multivariate probit model was generated as a dummy variable by assigning the value of 1 if the farmer adopted the particular strategy and the value of 0, if otherwise (Table 1).

The farmers were asked about their perceptions and experiences regarding the changes in climate over the previous years, and the adaptation strategies they practiced to cope with the changing climate conditions. Adaptation strategies employed by farmers to combat climate change include expanding irrigation, bund cropping, use of climate-resilient crop varieties, integration of livestock, shifting to non-farm activities, resorting to crop insurance, and adopting crop calendars. While most of the strategies were consistent with the adaptation strategies discussed in the literature, practices such as bund cropping and use of crop calendars found very little reference in the existing literature. Bunds refer to linear structures in the form of earthen mounds that divide rice fields and enable control of the water depth in the rice fields (Kumalasari and Bergmeier, 2014; Ali et al., 2019; Sattler et al., 2021). Planting vegetables or flowering plants on the bunds enables additional income as well as additional food for household consumption (Nguyen-Van-Hung et al., 2023).

### Independent variables

The independent variables used in the study include various determinants of climate change discussed in the reviewed empirical literature, FGDs,

| Dependent variables | Description of Variables | Source |
|---|---|---|
| Expanding Irrigation | 1, if adopted expansion of irrigation, 0 otherwise. | Hassan and Nhemachena, 2008; Abid et al., 2015; Jha and Gupta, 2021; Patel et al., 2023 |
| Bund Cropping | 1, if adopted bund cropping, 0 otherwise. | Kumalasari and Bergmeier, 2014; Ali et al., 2019; Sattler et al., 2021; Nguyen-Van-Hung et al., 2023 |
| Climate-resilient Crops | 1, if adopted high climate-resilient crops, 0 otherwise | Deressa et al., 2009; Abid et al., 2015; Jha and Gupta, 2021; Dhanya and Jayarajan, 2023; Patel et al., 2023 |
| Livestock | 1, if adopted practice of livestock rearing, 0 otherwise | Hassan and Nhemachena, 2008; Nhemachena et al., 2014; Patel et al., 2023 |
| Non-farm Activities | Shifting from farm to non-farm activities involving non-climate sensitive activities. 1, if engaged in non-farm activities, 0 otherwise | Jha and Gupta, 2021; Patel et al., 2023 |
| Crop Insurance | 1, if adopted crop insurance, 0 otherwise | Jha and Gupta, 2021; Dhanya et al., 2022 |
| Crop Calendar | 1, if adopted crop calendar, 0 otherwise | Wang et al., 2022 |

Source: Constructed by authors

Table 1: Description of dependent variables.

and discussions with farmers. The determinants include age (Hassan and Nhemachena, 2008; Abid et al., 2015; Megersa et al., 2022), gender (Funk et al., 2020), level of education (Teklewold et al., 2013), household size (Bahinipati and Venkatachalam, 2015; Destaw and Fenta, 2021), dependency ratio (Ingham et al., 2009; Jha and Gupta, 2021), farm size (Deressa et al., 2009), off-farm income (Vo et al., 2021), experience (Nhemachena et al., 2014), .access to credit facilities (Pattanayak et al., 2003; Khanal et al., 2018; Belay et al., 2022), and access to agricultural extension services (Asrat and Simane, 2018; Tesfaye and Nayak, 2022). Based on the FGDs, crop loss due to climate change and reduced cultivation season are included as independent variables.

In the Indian context, to understand the influence of socioeconomic status on the adaptation decisions of farmers, caste is used as an independent variable (Patil et al., 2018). The categories of caste include General, Other Backward Classes (OBC), Scheduled Caste (SC), and Scheduled Tribes (ST).

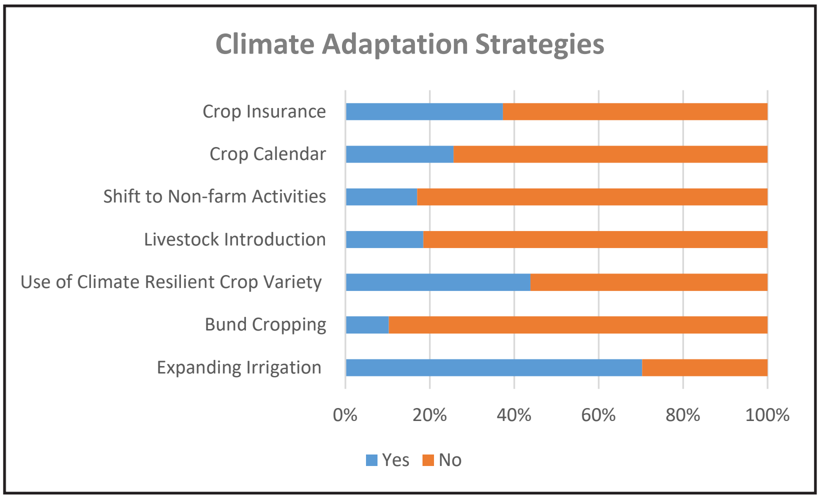
In the survey conducted, it was found that even though farmers had access to climate information through television, radio, etc., elderly farmers relied on their personal intuition in making decisions on farming. Therefore, the independent variable is taken as reliance on climate information, if the farmer chooses to rely on climate information rather than their personal intuition. Additionally, crop loss experienced by the farmers and reduced cultivation seasons were included as independent variables in this study since it was found to be an important variable in determining the choice of adaptation strategies as revealed by the survey. When a farmer experiences crop loss, he becomes more prepared in the future to deal with such exigencies by resorting to adaptation strategies. When farmers perceive any change in climate that would adversely impact their crops, they reduce cultivation during some seasons. Farmers who used to cultivate in three seasons a year had reduced cultivation to one or two seasons a year to reduce the incurrence of loss caused by climate change.

Perception of climate change is an important determinant of climate change adaptation decisions (Hassan and Nhemachena, 2008). While an increase in rainfall was associated with a greater incidence of floods, a prolonged decrease in rainfall was associated with reduced water availability and drought. Hence, both of these perceptions on change in rainfall had a significant influence on the adoption of climate change adaptation strategies (Ojo and Baiyegunhi, 2020). In the present study, the explanatory variables concerning the perception of climate change include the perception of an increase and decrease in annual rainfall received.

## Results and discussion

### Summary of choice of adaptation strategies

Figure 2 provides the summary of climate adaptation strategies adopted by farmers in terms of percentage. In the study area, majority of farm households (about 70 percent) resorted to expansion of irrigation as an adaptation strategy




Source: Calculated from the primary survey

Figure 2: Summary of climate adaptation strategies adopted by farmers.

to cope with climate change (with farmers cultivating in the Kayals of Kuttanad being an exception). Therefore, it could be inferred from the data that a high proportion of the farm households accorded high importance to expansion of irrigation as an adaptation strategy.

About 43 percent of the farm households switched to climate-resilient varieties of crops as an adaptation measure. While about 26 percent of the respondents resorted to the use of crop calendars, about 37 percent of farmers used insurance as a strategy to cope with climate change. Integration of livestock in the farming system and shifting to non-farm activities were considered adaptation measures by about 19 and 17 percentage of respondents respectively. Even though bund cropping was still practiced by about 10 percent of the surveyed farm households, their biggest challenge was wildlife crop raiding especially by wild boars, peacocks, and monkeys. Therefore, many farmers had to discontinue the strategy of bund cropping which they had practiced in the past as an effective adaptation measure to cope with climate change as well as during pest infestation in the main crop.

### Descriptive statistics of independent variables

The average age of the sampled households was 57.34 years, indicating a higher composition of older-generation farmers than the younger generation (see Appendix). The farm-level survey revealed that the farmers were generally older, largely because younger generations are hesitant to take up farming as a primary occupation due to reduced returns, increased cultivation expenses, and the unpredictability of climate conditions. The gender profile reveals that only 13 percent of the sampled households were female-headed, while the majority of 87 percent were male-headed. The average farm size of the households surveyed was 1.13 hectares. The education level of the farmers on average was 10 years. While 80 percent of the farmers faced crop loss due to climate change, 92 percent of the farmers had reduced cultivation seasons.

The field survey revealed that the farmers perceived changes in the timing of monsoons and the nature of accompanying rainfall over the years, while the farmers in all the three regions perceived an increase in temperature over the years. Further, the farmers of the Kuttanad region perceived an increase in rainfall and experienced floods, while the farmers of Palakkad district perceived a decrease in annual rainfall and experienced droughts.

### Correlation matrix of choice of adaptation strategies

The estimation results of the multivariate probit model show that the likelihood ratio test $Chi^2$ (21) = 45.63 with p > 0.0014 signifies acceptance of alternative hypothesis of the mutual interdependence of the error term of the different adaptation strategies (Table 2).

The adoption of insurance as a strategy was found to have significant negative correlation with non-farm activities and bund cropping. It could be inferred that the farmer would either choose crop insurance or engage in non-farm activities. A significant negative correlation was found to exist between non-farm activities and livestock as well as non-farm activities and the use of crop calendars, indicating substitutability among the adaptation choices. Further, it is also seen that a significant positive correlation exists between bund cropping and livestock indicating complementarities between the two strategies. Similarly, the strategies of using crop calendars and the use of climate-resilient crops exhibit complementarity, where the farmer uses both strategies together in combating climate change. The likelihood ratio test of the null hypothesis of interdependence between the adaptation strategies is rejected at 5% level of significance. The estimation of the correlation of error terms of selected climate adaptation strategies supports the suitability of multivariate probit model. The statistically significant pair-wise correlation coefficients of the error terms indicate correlation among the residuals of multiple climate adaptation strategies.

The determinants of climate adaptation strategies by the farmers are given in Table 3. The Wald test given by Wald $chi^2$ (128) = 883.07 and Prob > $chi^2$ = 0.0000 is highly significant indicating that the model is a good fit where the subsets of the coefficients of the model is jointly significant and the explanatory powers of the adaptation strategies are robust.

| Correlation Pairs | Coefficients | Standard error |
|---|---|---|
| Non-farm Activities and Expanding Irrigation | 0.0395 | 0.1395 |
| Crop Insurance and Expanding Irrigation | 0.0031 | 0.1092 |
| Livestock and Expanding Irrigation | -0.1179 | 0.1308 |
| Climate-resilient Crop and Expanding Irrigation | -0.1521 | 0.1253 |
| Bund cropping and Expanding Irrigation | 0.0372 | 0.1207 |
| Crop Calendar and Expanding Irrigation | -0.1445 | 0.1462 |
| Crop Insurance and Non-farm Activities | -0.2655*** | 0.1081 |
| Livestock and Non-farm Activities | -0.2845*** | 0.0889 |
| Climate-resilient Crop and Non-farm Activities | 0.0006 | 0.0984 |
| Bund cropping and Non-farm Activities | -0.0123 | 0.1069 |
| Crop Calendar and Non-farm Activities | -0.5019*** | 0.1474 |
| Livestock and Crop Insurance | -0.0575 | 0.0977 |
| Climate-resilient Crop and Insurance | -0.1002 | 0.1121 |
| Bund cropping and Crop Insurance | -0.2507** | 0.1047 |
| Crop Calendar and Crop Insurance | 0.2221 | 0.1396 |
| Climate-resilient Crop and Livestock | 0.0788 | 0.0987 |
| Bund cropping and Livestock | 0.2098** | 0.1015 |
| Crop Calendar and Livestock | 0.1788 | 0.1902 |
| Bund cropping and Climate-resilient Crop | -0.0682 | 0.1085 |
| Crop Calendar and Climate-resilient Crop | 0.3173** | 0.1304 |
| Crop Calendar and Bund cropping | -0.0882 | 0.1267 |
| Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0: chi2(21) = 45.63. Prob > chi2 = 0.0014 | | |

Note: ***, **, and * indicate levels of significance at p < 0.01, p < 0.05, and p < 0.1 respectively
Source: Calculated from the primary survey

Table 2: Correlation coefficients of selected climate adaptation strategies (from the Multivariate Probit Estimation).

| Adaptation Strategy | Expanding Irrigation | Bund Cropping | Climate-resilient Crops | Livestock | Non-farm Activities | Crop Insurance | Crop Calendar |
|---|---|---|---|---|---|---|---|
| Age | -0.0233 | 0.0256 | -0.0609*** | -0.0266* | -0.0357** | -0.0590*** | -0.0517** |
| Gender | -0.4364 | 0.7137** | -0.5215** | -0.5964*** | -0.2266 | -0.0104 | 0.2693 |
| Caste: OBC | -0.2209 | -0.1226 | -0.3671** | 0.3714** | -0.1388 | 0.0896 | 0.135 |
| SC | -0.2448 | 0.2145 | 0.4184 | 0.5988** | -0.4077 | -0.2861 | 0.8026* |
| ST | 3.8232 | 0.2212 | -5.7496 | -5.1078 | -5.4371 | -4.2463 | -3.7743 |
| Education (in years) | -0.1091* | 0.0138 | 0.0243 | 0.024 | -0.0387 | 0.1018** | 0.1460** |
| Household Size | -0.1547* | 0.0689 | 0.1131 | 0.1849*** | -0.1694** | 0.0223 | -0.0923 |
| Dependency Ratio | -0.8149 | -0.4913 | -0.7112 | 0.9799* | -0.247 | -1.2532** | -1.0452 |
| Experience | -0.0103 | -0.0006 | 0.017 | 0.007 | 0.0093 | 0.0049 | -0.0073 |
| Farm Size (in hectares) | 0.0173 | 0.3354*** | 0.0436 | 0.2574*** | 0.5391* | 1.0276*** | 0.4781*** |
| Off-farm Income | -0.0377 | 0.2119 | -0.1694 | -0.174 | 0.0557 | -0.1527 | 1.1945*** |
| Access to Agricultural extension Services | 0.4116* | -0.0507 | 0.2864 | 0.4079** | 0.0987 | -0.171 | -0.5335** |
| Ease of Agricultural Credit Access | 0.7246*** | -0.2862 | -0.3101 | -0.2687 | 0.0867 | -0.0339 | -0.4837* |
| Climate Information Access | -0.1436 | 0.4509** | -0.0451 | 0.2962 | 0.2205 | 0.1877 | -0.2036 |
| Crop Loss due to Climate Change | -0.1624 | -0.1948 | 0.2238 | -0.1705 | -0.0272 | 0.6041*** | -0.1154 |
| Reduced Cultivation Season | 0.0611 | 0.6793* | 0.0972 | 0.2634 | -0.1288 | -0.5796* | 0.2922 |
| Perception of Increase in Rainfall | -2.6731*** | -1.2148*** | 3.0853*** | -1.2976*** | -6.5408 | 1.0202*** | 2.6383*** |
| Perception of Decrease in Rainfall | 0.3664 | -0.4285** | 0.0429 | -0.0421 | 0.1932 | -1.1382*** | -1.2005** |
| Constant | 5.9760*** | -4.0277*** | 2.0528 | -1.2496 | 1.9469 | 1.3890 | -0.4867 |

Note: ***, **, and * indicate levels of significance at p < 0.01, p < 0.05, and p < 0.1 respectively
Source: Calculated from the primary survey

Table 3: determinants of climate adaptation strategies by the farmers using multivariate probit model.

### Expanding irrigation

Expansion of irrigation was adopted primarily in the regions of Palakkad Plain and the High Hills. The results revealed that a lower level of education meant an increase in the probability of expansion of irrigation by 0.02, implying that lesser-educated farmers were more likely to adopt the strategy of expanding irrigation. However, it is to be noted that the farmers on average had 10 years of education, indicating a higher literacy level. Less educated farmers include mainly aged farmers who rely on traditional farming practices and irrigation. Further, it was found that the ease of availing agricultural credit substantially increases the likelihood of the adopting the strategy of expanding irrigation by 0.72. Farm households with better access to credit were more likely to make decisions on adopting adaptation strategies as it provided them relief from various financial constraints (Deressa et al., 2009; Pattanayak et al., 2003; Khanal et al., 2018; Belay et al., 2022). The field survey reveals that out of the total agricultural credit availed, about 5 per cent had been incurred for the purchase of pump sets and enhancement of other irrigation facilities. Very often the farmers had to make a trade-off between utilising the agricultural credit towards financing either new cultivation or any other specific investment requirement such as irrigation indicating that credit facilities were a means of limited finance.

Access to agricultural extension services significantly boosted the likelihood of adopting the strategy of expansion of irrigation (by 0.41) since they are an important source of information on both agronomic services and climate as stated in the existing literature (Hassan and Nhemachena, 2008; Asrat and Simane, 2018). Further, the results reveal that farmers would not think of expanding irrigation if they perceived an increase in rainfall.

### Bund cropping

Bund cropping in in the study regions was practiced mostly in the Palakkad Plain, even though the practice was adopted less in the High Hills. Age endows the farmer with experience that helps in better assessment of risks (Megersa et al., 2022). Farmers are keen observers of the changes in climate and make decisions based on their past experiences (Mahmood et al., 2021). Further, the results show that male headed households have a higher probability of resorting to the strategy of bund cropping as revealed by the coefficient of 0.71 at 5 per cent level of significance. Existing literature associates the increased probability of adaptation with higher off-farm income as it empowers the farmer to consider even costlier options of adaptation measures (Deressa et al., 2009; Vo et al., 2021). Additionally, the farm size positively determined the adoption of bund cropping signifying that households with larger farm sizes had higher likelihood of adopting the strategy (by 0.34). Access to climate information increased the probability of adopting bund cropping. This could be because reliability of climate information enables the farmers to make informed decisions on the crop to be cultivated on the bunds. It is further seen that a reduction in cultivation season significantly increases the probability of adopting bund cropping (by 0.68) as it implies making up for the reduction in revenue for the farmers. However, it is observed from the field survey that most of the farmers practiced bund cropping for consumption within the household rather than for commercial purposes. The perception of both increased and decreased rainfall negatively influenced the adoption of bund cropping. From the field survey, it has been observed that the practice of bund cropping has been discontinued by a few farmers in recent times due to increased instances of animal crop-raiding by mainly wild boars, monkeys, and peacocks.

### Climate-resilient crops

The rice varieties generally used by farmers were Uma, Jyothy, Jaya, etc. based on the duration of cultivation, high productivity, resistance to pests, and better resistance to warmer temperatures (Dhanya and Jayarajan, 2023). Traditional varieties of rice are also cultivated due to its agro-climatic suitability, affordability due to its low input-intensive nature, and resilience especially under changing climate conditions (Rasheed et al., 2021b). The cultivation of traditional varieties of rice such as Veliyan, Thondi, Jeerakasala, Gandhakasala, etc., was prevalent in the High Hill region of Wayanad district.

The use of climate-resilient varieties of crops was influenced by age and gender negatively, indicating a higher likelihood of adoption by younger farmers (by 0.06) and female-headed households (by 0.52). The empirical literature points out the varying impact of age on a farmer's decision to adapt. The younger farmers are expected to have a longer horizon of planning and are capable of undertaking long-term adaptation measures such as irrigation or adopting a mixture of crop-livestock strategies (Hassan and Nhemachena, 2008). From the field survey, it was observed that the farmers of the Scheduled Tribes or the indigenous community in the High Hill region of Wayanad actively cultivated traditional rice varieties rather than any high-yielding varieties as they felt that these crops were more tolerant to climate change. Further, the result reveals a significant positive influence on the perception of increased rainfall in adopting climate-resilient crop varieties.

### Livestock

The strategy of introducing livestock means that even when the main crop does not do well due to climate change, an alternative option exists for the farmers (see Nhemachena et al., 2014). The results reveal that younger generation farmers (by 0.03) and female headed farm households (by 0.60) have an increased probability of integrating livestock with the existing farming system. In comparison to the general category farmers, the farmers belonging to the OBC (by 0.37) and SC (by 0.60) categories significantly increased likelihood of adopting the strategy of livestock introduction to cope with climate change. The size of farm has a significant positive influence on introduction of livestock as indicated by a coefficient of 0.26 at 1% level of significance, corroborating the influence of farm size on adaptation strategies as evinced in the reviewed literature (Asrat and Simane, 2018; Aryal et al., 2020). A high dependency ratio indicates higher dependency burden on the working population due to increased responsibility to feed the dependents and larger expenditure (Ingham et al., 2009; Jha and Gupta, 2021). Larger household size indicating availability of larger manpower on the farm influences the introduction of livestock into the farming system, which is in agreement with the results of Funk et al. (2020). Due to the higher labour endowment associated with larger household size, many empirical studies have found household size to be a positive determinant of adaptation decision (Abid et al., 2015; Destaw and Fenta, 2021; Megersa et al., 2022). Further, the perception of increased rainfall is found to have a significant negative impact on introducing livestock.

### Non-farm activities

Lower age and smaller household size significantly increased the probability of making adaptation decision of diversification from farming to non-farm activities to cope with climate change by 0.04 and 0.17 respectively, while larger farm size increased the probability 0.53. Age is found to have a negative relationship with shifting to non-farm activities, indicating the aversion of elderly farmers to digressing from their main occupation of rice cultivation. The results further show that while the larger household size dissuades the farmer from shifting to non-farm activities, the size of the farm exercises a significant positive impact on shifting to non-farm activities. Since farm size indicates the wealth endowment of a farmer, larger farm size is associated with an increased capacity of the farmer to adopt adaptation strategies (Deressa et al., 2009). In other words, a larger farm size enables the farmer to diversify to other activities to minimize risk of climate change.

### Crop insurance

Younger farmers exhibit a greater likelihood of resorting to insurance as an adaptation strategy as indicated by the negative coefficient of 0.06 at 5% level of significance. It is observed that the higher education level of the farmer increases the probability of the farmer adopting crop insurance by 0.10. The education level of farmers plays an important role in their understanding of the risks associated with climate change, and access to scientific information, enabling the farmer to plan and make decisions on suitable adaptation strategies to be implemented to reduce the risks arising thereon (Aryal et al., 2020; Mahmood et al., 2021; Destaw and Fenta, 2021). If the dependency ratio is higher, it is less likely that the farmer would adopt crop insurance. Larger farm size increased the probability of resorting to crop insurance. The results further show that the past experience of crop loss due to climate change significantly increased the probability of resorting to crop insurance as indicated by the coefficient of 0.60. The cost of cultivation incurred could be high for the farm households having larger farms, and therefore they resort to crop insurance to make good the loss in the case of extreme climate events. Farmers resorting to crop insurance due to past experience of crop loss is indicative of the fact that they anticipate the occurrence of extreme climate events which are likely to reduce their farm income. Reduced crop cultivation and the perception of a decrease in rainfall have a significantly negative impact on the adoption of crop insurance. The perception of higher rainfall positively influences the adaptation choice of resorting to crop insurance.

Furthermore, it is observed that all farmers do not adopt the strategy of crop insurance due to issues confronting availing claims during crop loss. From the policy perspective, an increase in the number of weather stations or observatories would help in improving the real-time monitoring of weather parameters. These would act as stations for recording proximate weather parameters during the event of crop loss which increases the farmers' chance of availing insurance claims. An increase in the number of claims would encourage more farmers to adopt the strategy of crop insurance.

### Crop calendar

The younger generation of farmers have a higher probability of resorting to crop calendars as an adaptation strategy towards coping with climate change as indicated by the coefficient of 0.05 at 5% level of significance. The farmers opine that crop calendars would also bring uniformity in the cultivation and harvesting of crops, enabling even farmers with small and fragmented landholdings to reap the economies of cultivating together. The education level, and farm size significantly increase the probability of the use of crop calendars by 0.15 and 0.48 respectively. The results reveal that as the access to agricultural extension services and agricultural credit diminishes, the probability of adopting the strategy of crop calendars increased by 0.53 and 0.48 respectively. Further, if the farmers perceive an increase in rainfall they are more likely to opt for the use of crop calendars, while they are less likely to prefer crop calendars if they perceive decreased rainfall. However, it is to be noted that the crop calendars need to be prepared for each agro-ecological zone or unit with utmost care by the government entities operating at the grass-root level, in consonance with the meteorological department ensuring its reliability for the farmers. However, the development and preparation of crop calendars is an area of study which requires the use of scientific knowledge and technology, coupled with stakeholder deliberations aimed at fostering broader acceptance and adoption by the farmers.

A limitation of this study is that it analyses only the determinants of climate adaptation strategies of three agro-ecological zones of Kerala, while a more comprehensive disaggregate analysis incorporating all AEZs of Kerala that cultivates paddy would provide insights into diverse climate change adaptation strategies followed in each zone enabling tailored policy suggestions for each zone. However, the focus of this study was on the determinants of climate change adaptation strategy among the rice-farmers of Kerala considering the three AEZs together.

## Conclusion

Adaptation has become imminent for farmers due to the evident changes in climate, enabling them to secure their livelihood, ensure food security, and earn a better income, which constitutes their primary objective of engaging in farming activity. However, the choice of adaptation strategy employed by the farmer is determined by a multiplicity of factors. This study analysed the determinants of climate change adaptation strategies among the rice farmers of Kerala employing a multivariate probit model. The adaptation strategies and their determinants were identified from the literature and the information collected from the farmers through FGDs. The results revealed both positive and negative correlations among the adaptation strategies employed by the farm households to cope with climate change signifying interdependence among various adaptation strategies, thereby justifying the use of a multivariate probit model in this study. The results of the multivariate probit model further revealed that the farmers' choice of adaptation strategies is majorly determined by the factors, age, farm size, and the perception of increased rainfall.

However, specific policy actions of the government are warranted to make agriculture sustainable for the farmers, by improving their adaptive capacity (Bahinipati and Venkatachalam, 2015). Government policies towards improving access to affordable credit would aid the farmer in adopting better adaptation strategies. The policy of enhancement of easier access to credit facilities especially targeting the expansion of irrigation facilities is required since the credit availed by the farmers is very limited and is spent on other purposes such as cultivation of crops or for the purchase of other inputs, rather than in methods to improve their resilience to climate change. Further, the timely availability of credit with zero or minimal interest rates would encourage more farmers to access affordable financing options. Moreover, it is found that farmers rely on personal intuition rather than the available climate information, even though they have access to it. This is due to the non-reliability of the available climate information. To provide reliable information, government intervention is inevitable especially through investment in research and development to deliver more accurate predictions on climate inputs such as rainfall, temperature, wind, and extreme climatic conditions to the farmers. Furthermore, access to agricultural extension services continues to be an issue that needs to be addressed (as corroborated by Funk et al., 2020) by the government to educate the farmers on government policies and schemes, and also to provide services related to improved production technologies and adaptation strategies. Policies towards increasing the number of weather stations or observatories and usage of kisan drones to assess the crops grown and loss incurred would indirectly incentivise farmers to adopt crop insurance as an adaptation strategy by easing the process of insurance claims and fostering transparency (also suggested by Patel et al., 2023). Additionally, preparation of accurate and reliable crop calendars in consultation with the meteorological department and stakeholders would constitute an inclusive approach towards improving the resilience of the farmers towards climate change. In conclusion, along with the household and socio-economic determinants, institutional support to farmers through appropriate policy measures, enhance their adaptative capabilities to cope with climate change.

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## References

[1] Abid, M., Scheffran, J., Schneider, U. A. and Ashfaq, M. (2015) "Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan", *Earth System Dynamics*, Vol. 6, No. 1, pp. 225-243. E- ISSN 2190-4987. DOI 10.5194/esd-6-225-2015.

[2] Ali, M. P., Bari, M. N., Haque, S. S., Kabir, M. M. M., Afrin, S., Nowrin, F., Islam, M. S. and Landis, D. A. (2019) "Establishing next-generation pest control services in rice fields: eco-agriculture", *Scientific Reports*, Vol. 9, No. 1. ISSN 2045-2322. DOI 10.1038/s41598-019-46688-6.

[3] Aryal, J. P., Sapkota, T. B., Rahut, D. B., Krupnik, T. J., Shahrin, S., Jat, M. L. and Stirling, C. M. (2020) "Major Climate risks and Adaptation Strategies of Smallholder Farmers in Coastal Bangladesh", *Environmental Management*, Vol. 66, No. 1, pp. 105-120. E-ISSN 1432-1009. DOI 10.1007/s00267-020-01291-8.

[4] Aswathi, K. P., Ajith, K., Ajithkumar, B. and Abida, P. S. (2022) "Impact of climate change on rice yield under projected scenarios in central zone of Kerala", *Journal of Agrometeorology*, Vol. 24, No. 3, pp. 280-285. E-ISSN 2583-2980, ISSN 0972-1665. DOI 10.54386/jam.v24i3.1544.

[5] Asrat, P. and Simane, B (2018) "Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia", *Ecological Processes*, Vol. 7, No. 1. ISSN 2192-1709. DOI 10.1186/s13717-018-0118-8.

[6] Auffhammer, M., Ramanathan, V. and Vincent, J. R. (2012) "Climate change, the monsoon, and rice yield in India", *Climatic Change*, Vol. 111, No. 2, pp. 411-424. ISSN 1573-1480. DOI 10.1007/s10584-011-0208-4.

[7] Bahinipati, C. S. and Venkatachalam, L. (2015) "What drives farmers to adopt farm-level adaptation practices to climate extremes: Empirical evidence from Odisha, India", *International Journal of Disaster Risk Reduction*, Vol. 14, No. 4, pp. 347-356. ISSN 2212-4209. DOI 10.1016/j.ijdrr.2015.08.010.

[8] Belay, A. D., Kebede, W. M. and Golla, S. Y. (2023) "Determinants of climate-smart agricultural practices in smallholder plots: evidence from Wadla district, northeast Ethiopia. International", *Journal of Climate Change Strategies and Management*, Vol. 15, No. 5, pp. 619-637. E-ISSN 1756-8706. DOI 10.1108/ijccsm-06-2022-0071.

[9] Chib, S. and Greenberg, E. (1998) "Analysis of multivariate probit models", *Biometrika*, Vol. 85, No. 2, pp. 347-361. E-ISSN 1464-3510. DOI 10.1093/biomet/85.2.347.

[10] Connor, M., Gummert, M., and Singleton, G. R. (eds) (2023) "*Closing rice yield gaps in Asia*", Springer. ISBN 978-3-031-37947-5. DOI 10.1007/978-3-031-37947-5.

[11] Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. and Yesuf, M. (2009) "Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia", *Global Environmental Change*, Vol. 19, No. 2, pp. 248-255. ISSN 0959-3780. DOI 10.1016/j.gloenvcha.2009.01.002.

[12] Destaw, F. and Fenta, M. M. (2021) "Climate change adaptation strategies and their predictors amongst rural farmers in Ambassel district, Northern Ethiopia", *Jàmbá: Journal of Disaster Risk Studies*, Vol. 13, No. 1, pp. 1-11. ISSN 1996-1421. DOI 10.4102/jamba.v13i1.974.

[13] Dhanya, P., Ramachandran, A. and Palanivelu, K. (2022) "Understanding the local perception, adaptation to climate change and resilience planning among the farmers of semi-arid tracks of South India", *Agricultural Research*, Vol. 11, pp. 291-308. ISSN 2249-7218. DOI 10.1007/s40003-021-00560-0.

[14] Dhanya, P. and Jayarajan, K (2023) "The ecological significance to maintain rice cropping areas in the rice bowls of Kerala for sustaining food security under the purview of climate change", In: Alam, A., Rukhsana (eds) "*Climate Change, Agriculture and Society*", pp. 159-173. Springer. ISBN 978-3-031-28251-5. DOI 10.1007/978-3-031-28251-5_9.

[15] Directorate of Environment and Climate Change (2022) "*Kerala State Action Plan on Climate Change 2.0 (2023-2030)*". Department of Environment, Government of Kerala. [Online]. Available: https://envt.kerala.gov.in/wp-content/uploads/2022/12/Kerala-State-Action-Plan-on-Climate-Change-2.0.pdf [Accessed: Jan. 15, 2024].

[16] Funk, C., Sathyan, A. R., Winker, P. and Breuer, L. (2020) "Changing climate-Changing livelihood: smallholder's perceptions and adaption strategies", *Journal of Environmental Management*, Vol. 259. ISSN 1095-8630. DOI 10.1016/j.jenvman.2019.109702.

[17] Government of Kerala (2022) "*Agricultural Statistics: 2020-21*". Department of Economics and Statistics. [Online]. Available: https://ecostat.kerala.gov.in/storage/publications/622.pdf [Accessed: Jan. 20, 2024].

[18] Gupta, S., Sen, P. and Srinivasan, S. (2014) "Impact of Climate Change on the Indian Economy: Evidence from Food Grain Yields", *Climate Change Economics*, Vol. 5, No. 2. ISSN 2010-0086. DOI 10.1142/S2010007814500018.

[19] Hassan, R. M. and Nhemachena, C. (2008) "Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis", *African Journal of Agricultural and Resource Economics*, Vol. 1, No. 2, pp. 83-104. ISSN 2521-9871. DOI 10.22004/ag.econ.56969.

[20] Ingham, B., Chirijevskis, A. and Carmichael, F. (2009) "Implications of an increasing old-age dependency ratio: The UK and Latvian experiences compared", *Pensions: An International Journal*, Vol. 14, pp. 221-230. ISSN 1478-5315. DOI 10.1057/pm.2009.16.

[21] Intergovernmental Panel on Climate Change (2023) "Climate Change 2023. Synthesis Report", A Report of the Intergovernmental Panel on Climate Change. DOI 10.59327/IPCC/AR6-9789291691647.001.

[22] Jha, C. K. and Gupta, V. (2021) "Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India", *Environmental and Sustainability Indicators*, Vol. 10, pp. 100-112. ISSN 2665-9727. DOI 10.1016/j.indic.2021.100112.

[23] Joseph, M., Moonsammy, S., Davis, H., Warner, D., Adams, A. and Oyedotun, T. D.T. (2023) "Modelling climate variabilities and global rice production: A panel regression and time series analysis", *Heliyon*, Vol. 9, No. 4. ISSN 2405-8440. DOI 10.1016/j.heliyon.2023.e15480.

[24] Kerala Agricultural University (2020) "*Agroecological zones of Kerala: Delineation and cropping pattern*". [Online]. Available: https://pop.kau.in/agro-ecologicalzonesofkerala.htm [Accessed: Jan. 10, 2024].

[25] Kerala State Planning Board (2021) "*Kerala Economic Review 2020*". Government of Kerala. [Online]. Available: https://spb.kerala.gov.in/sites/default/files/2021-01/English-Vol-2_0.pdf [Accessed:Jan. 10, 2024].

[26] Khanal, U., Wilson, C., Hoang, V. N. and Lee, B. (2018) "Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal", *Ecological Economics*, Vol. 144, pp. 139-147. ISSN 0921-8009. DOI 10.1016/j.ecolecon.2017.08.006.

[27] Kumalasari, N. R. and Bergmeier, E. (2014) "Effects of surrounding crop and semi-natural vegetation on the plant diversity of paddy fields", *Agriculture and Food Security*, Vol. 3, No. 15. ISSN 2048-7010. DOI 10.1186/2048-7010-3-15.

[28] Mahmood, N., Arshad, M., Mehmood, Y., Shahzad, M. F. and Kächele, H. (2021) "Farmers' perceptions and role of institutional arrangements in climate change adaptation: Insights from rainfed Pakistan", *Climate Risk Management,* Vol. 32. ISSN 2212-0963. DOI 10.1016/j.crm.2021.100288.

[29] Megersa, G. G., Jaleta, M., Tesfaye, K., Getnet, M., Tana. T. and Lakew, B. (2022) "Perceived climate change and determinants of adaptation responses by smallholder farmers in Central Ethiopia", *Sustainability*, Vol. 14, No. 11. ISSN 2071-1050. DOI 10.3390/su14116590.

[30] Mulwa, C., Marenya, P., Rahut, D. B. and Kassie, M. (2017) "Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics", *Climate Risk Management*, Vol. 16, pp. 208-221. ISSN 2212-0963. DOI 10.1016/j.crm.2017.01.002.

[31] Nguyen-Van-Hung et al. (2023) "Innovations, Technologies, and Management Practices for Sustainable Rice Production". In: Connor, M., Gummert, M., Singleton, G. R. (eds) "*Closing Rice Yield Gaps in Asia",* Springer, pp. 121-148. ISBN 978-3-031-37947-5. DOI 10.1007/978-3-031-37947-5_4.

[32] Nhemachena, C., Hassan, R. and Chakwizira, J. (2014) "Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa", *Journal of Development and Agricultural Economics*, Vol. 6, No. 5, pp. 232-241. ISSN 2006-9774. DOI 10.5897/JDAE12.0441.

[33] Ojo, T. O. and Baiyegunhi, L. J. S. (2020) "Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria", *Land Use Policy*, Vol. 95. ISSN 1873-5754. DOI 10.1016/j.landusepol.2019.04.007.

[34] Ojo, T. and Baiyegunhi, L. (2018) "Determinants of adaptation strategies to climate change among rice farmers in Southwestern Nigeria: A multivariate probit approach", *2018 Conference,* July 28-August 2, 2018, Vancouver, British Columbia 277011, International Association of Agricultural Economists. DOI 10.22004/ag.econ.277011.

[35] Patel, S., Mall, R. K., Chaturvedi, A., Singh, R. and Chand, R. (2023) "Passive adaptation to climate change among Indian farmers", *Ecological Indicators,* Vol. 154. p. 110637. ISSN 1872-7034. DOI 10.1016/j.ecolind.2023.110637.

[36] Patil, V. S., Thomas, B. K., Lele, S., Eswar, M. and Srinivasan, V. (2018) "Adapting or chasing water? Crop choice and farmers' responses to water stress in peri-urban Bangalore, India", *Irrigation and Drainage*, Vol. 68, No. 2, pp. 140-151. ISSN 1531-0361. DOI 10.1002/ird.2291.

[37] Pattanayak, S. K., Mercer, D. E., Sills, E. and Yang, J. C. (2003) "Taking stock of agroforestry adoption studies", *Agroforestry Systems*, Vol. 57, pp. 173-186. ISSN 1572-9680. DOI 10.1023/A:1024809108210.

[38] Rajiv Gandhi Institute of Development Studies (2018) "*A Report on Kerala floods 2018: The disaster of the century*". [Online]. Available: https://sdma.kerala.gov.in/wp-content/uploads/2020/08/Rajeev-Gandhi-Centre-Kerala-flood-2018-The-disaster-of-the-century.pdf [Accessed: Jan. 10, 2024].

[39] Rao, C. A. R., Raju, B. M. K., Islam, A., Rao, A.V. M. S., Rao, K. V., Chary, G. R., Kumar, R. N., Prabhakar, M., Reddy, K. S. and Chaudhari, S. K. (2019) "*Risk and vulnerability assessment of Indian agriculture to climate change", ICAR-Central Research Institute for Dryland Agriculture.* [Online]. Available: https://www.icar-crida.res.in/assets_c/img/Books/Atlas%20climate%20change%20Aug%202020.pdf [Accessed: Jan. 15, 2024].

[40] Raosoft (2004) "*Raosoft Sample Size Calculator*" Raosoft, Inc., Seattle. [Online]. Available: http://www.raosoft.com/samplesize.html [Accessed: Feb. 8, 2024].

[41] Rasheed, S., Venkatesh, P., Singh, D. R., Renjini, V. R., Jha, G. K. and Sharma, D. K. (2021a) "Ecosystem valuation and eco-compensation for conservation of traditional paddy ecosystems and varieties in Kerala, India", *Ecosystem Services*, Vol. 49. ISSN 2212-0416. DOI 10.1016/j.ecoser.2021.101272.

[42] Rasheed, S., Venkatesh, P., Singh, D. R., Renjini, V. R., Jha, G. K. and Sharma, D. K. (2021b) "Who cultivates traditional paddy varieties and why? Findings from Kerala, India", *Current Science*, Vol. 121, No. 9, pp. 1188-1193. ISSN 0011-3891. DOI 10.18520/cs/v121/i9/1188-1193.

[43] Reddy, K. V., Paramesh, V., Arunachalam, V., Das, B., Ramasundaram, P., Pramanik, M., Sridhara, S., Reddy, D. D., Alataway, A., Dewidar, A. Z. and Mattar, M. A. (2022) "Farmers' perception and efficacy of adaptation decisions to climate change", *Agronomy*, Vol. 12, No. 5. E-ISSN 2073-4395. DOI 10.3390/agronomy12051023.

[44] Regmi, H. P., Upendram, S., Cho, S. H. and Clark, C. D. (2023) "Examining complementary relationships among climate change adaptation practices of rice producers in Chitwan, Nepal", *Climate and Development*, Vol. 15, No. 6, pp. 480-500. E-ISSN 1756-5537. DOI 10.1080/17565529.2022.2107980.

[45] Sattler, C., Schrader, J., Flor, R. J., Keo, M., Chhun, S., Choun, S., Hadi, B. A. R. and Settele, J. (2021) "Reducing pesticides and increasing crop diversification offer ecological and economic benefits for farmers—A case study in Cambodian rice fields", *Insects*, Vol. 12, No. 3. E-ISSN 2075-4450. DOI 10.3390/insects12030267.

[46] Shine, I. (2023) "*Rising global temperatures are already affecting the tourism industry - here's how*", World Economic Forum. [Online]. Available: https://www.weforum.org/agenda/2023/08/temperatures-tourism-climate-impact/ [Accessed: Jan. 10, 2024].

[47] Swain, D. K. and Thomas, D. (2010) "Climate change impact assessment and evaluation of agro-adaptation measures for rice production in eastern India", *Journal of Environmental Informatics*, Vol. 16, No. 2, pp. 94-101. ISSN 1726-2135. DOI 10.3808/jei.201000181.

[48] Swami, D. and Parthasarathy, D. (2020) "A multidimensional perspective to farmers' decision making determines the adaptation of the farming community", *Journal of Environmental Management*, Vol. 264, pp. 110487-110487. ISSN 1095-8630. DOI 10.1016/j.jenvman.2020.110487.

[49] Swaminathan, M. S. and Kesavan, P. C. (2012) "Agricultural research in an era of climate change", *Agricultural Research*, Vol. 1, pp. 3-11. ISSN 2249-7218. DOI 10.1007/s40003-011-0009-z.

[50] Teklewold, H., Kassie, M., Shiferaw, B. and Köhlin, G. (2013) "Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor", *Ecological Economics*, Vol. 93, pp. 85-93. ISSN 1873-6106. DOI 10.1016/j.ecolecon.2013.05.002.

[51] Tesfaye, T. and Nayak, D. (2022) "Does participation in non-farm activities provide food security? Evidence from rural Ethiopia", *Cogent Social Sciences*, Vol. 8, No. 1. ISSN 2331-1886. DOI 10.1080/23311886.2022.2108230.

[52] van Ruijven, B. J., De Cian, E. and Wing S. I. (2019) "Amplification of future energy demand growth due to climate change", *Nature Communications*, Vol. 10. ISSN 2041-1723. DOI 10.1038/s41467-019-10399-3.

[53] Varghese, S. J., Surendran, S., Ajithkumar, B., Rajendran, K. and Kitoh, A. (2020) "Future changes in rice yield over Kerala using climate change scenario from high resolution global climate model projection", *Journal of Earth System Science*, Vol. 129, pp. 1-17. ISSN 0973-774X. DOI 10.1007/s12040-020-01459-0.

[54] Vo, H. H., Mizunoya, T. and Nguyen, C. D. (2021) "Determinants of farmers' adaptation decisions to climate change in the central coastal region of Vietnam", *Asia-Pacific Journal of Regional Science*, Vol. 5, pp. 327-349. ISSN 2509-7954. DOI 10.1007/s41685-020-00181-5.

[55] Wang, X., Folberth, C., Skalsky, R., Wang, S., Chen, B., Liu, Y., Chen, J. and Balkovic, J. (2022) "Crop calendar optimization for climate change adaptation in rice-based multiple cropping systems of India and Bangladesh", *Agricultural and Forest Meteorology*, Vol. 315. ISSN 1873-2240. DOI 10.1016/j.agrformet.2022.108830.

[56] Yalew, S. G., van Vliet, M. T. H., Gernaat, D. E. H. J., Ludwig, F., Miara, A., Park, C., Byers, E., De Cian, E., Piontek, F., Iyer, G., Mouratiadou, I., Glynn, J., Hejazi, M., Dessens, O., Rochedo, P., Pietzcker, R., Schaeffer, R., Fujimori, S., Dasgupta, S., Mima, S., Santos da Silva, S. R., Chaturvedi, V., Vautard, R. and van Vuuren, D. P. (2020) "Impacts of climate change on energy systems in global and regional scenarios", *Nature Energy*, Vol. 5, No. 10, pp. 794-802. ISSN 2058-7546. DOI 10.1038/s41560-020-0664-z.

# Appendix

| Independent variables | Data Type | Mean | Std. Dev. |
|---|---|---|---|
| Age | Continuous | 57.34 | 10.67 |
| Gender | Binary (1 = Male, 0 = Female) | 0.87 | 0.33 |
| Caste: | | | |
| General | Binary | 0.39 | 0.49 |
| OBC | Binary | 0.50 | 0.50 |
| SC | Binary | 0.06 | 0.24 |
| ST | Binary | 0.06 | 0.23 |
| Education (in years) | Continuous | 10.04 | 3.08 |
| Household Size | Continuous | 4.65 | 1.14 |
| Dependency Ratio | Continuous | 0.68 | 0.15 |
| Experience | Continuous | 39.64 | 14.65 |
| Farm Size (in hectares) | Continuous | 1.13 | 0.92 |
| Non-farm Income | Binary (1 = Yes, 0 = No) | 0.72 | 0.45 |
| Access to Agricultural Extension Services | Binary (1 = Yes, 0 = No) | 0.44 | 0.50 |
| Ease of Access to Agricultural Credit | Binary (1 = Yes, 0 = No) | 0.77 | 0.42 |
| Reliance on Climate Information | Binary (1 = Yes, 0 = No) | 0.42 | 0.49 |
| Crop Loss due to Climate Change | Binary (1 = Yes, 0 = No) | 0.80 | 0.40 |
| Reduced Cultivation Season | Binary (1 = Yes, 0 = No) | 0.92 | 0.28 |
| Perception of Increase in Rainfall | Binary (1 = Yes, 0 = No) | 0.34 | 0.48 |
| Perception of Decrease in Rainfall | Binary (1 = Yes, 0 = No) | 0.31 | 0.46 |

Source: Calculated from the primary survey

Table A1: Summary statistics of independent variables.