Assessing Climate change impacts on crop Productivity and adaptation strategies at the farm household level in India

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Background of the study

- Numerous studies demonstrate that climate change has a disproportionately negative impact on agricultural and smallholder farming systems in poor nations, including India (Bandara and Cai, 2014; Kahsay and Hansen, 2016).
- It jeopardises food security and agricultural development goals – namely, raising farmer income and reducing poverty (FAO, 2014).
- Agriculture in India, which accounts for around 16% of total GDP and employs approximately 49% of total employment (Economic and Survey, 2017 -18), is being threatened by the potential consequences of climate change and variability.
- Adaptation to climate change has been classified in the literature as either autonomous or planned (IPCC, 2007).

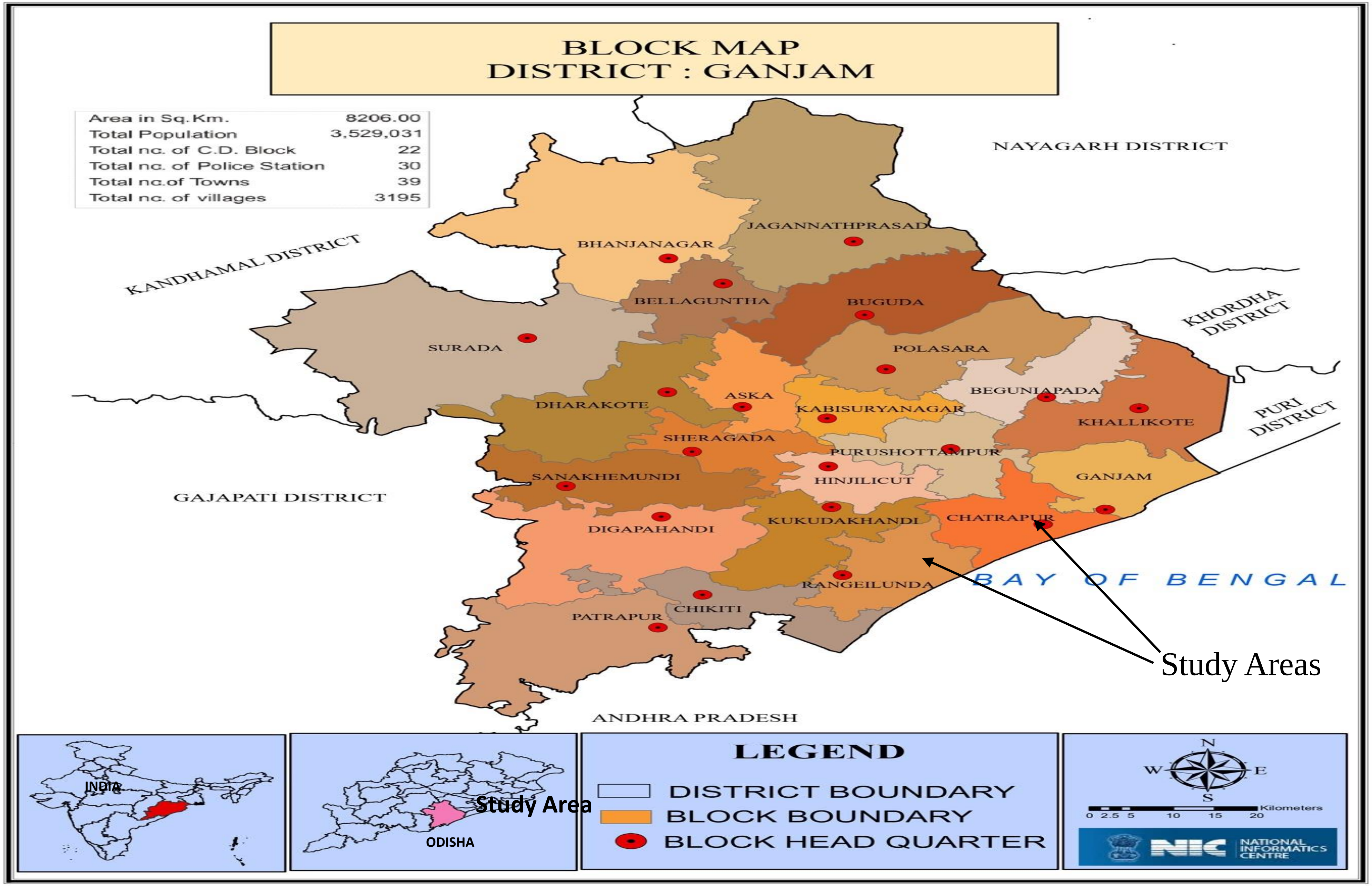
Why Odisha

- Odisha, one of India’s eastern states, is regarded as the most vulnerable to natural disasters.
- The agriculture of Odisha is vulnerable to the unfavourable consequences of climate change.
- It has been established that just 13years out of 52 have normal rainfall, giving the state a 75% probability of being hit by a natural calamity of any kind (Natural Disaster Plan for Odisha, 2014).
- These natural disasters have a significant impact on crop production and productivity.
- For instance, after a solid agricultural growth rate of 12.30% in 2012– 2013, the state experienced a negative growth rate in 2013 to 2014, owing mostly to super-cyclonic storm Phailin and flash flooding (Odisha Economic Survey, 2014–2015).

Table 1: Chronology of Natural Calamities in Odisha during last ten years (2010-2020)

Year	Natural Calamities
2010	Flood, Heavy Rain, Drought & unseasonal cyclonic rain
2011	Drought & flood
2012	Drought & flood
2013	Very Severe Cyclonic Storm "Phailin", flood
2014	Very Severe Cyclonic Storm "Hudhud", flood
2015	Drought, flood & heavy rain
2016	Drought, flood & heavy rain
2017	Flood, Heavy Rain, Drought & Pest Attack, Unseasonal Rain
2018	Cyclonic Storm "Titli" and “Pethai” / Drought
2019	Extremely Severe Cyclonic Storm "Fani" and “Bulbul”
2020	Severe Cyclone “AMPHAN” and heavy flood

Study Area Maps



Objectives of the study

- To examine the effects of climate change on crop productivity, with special reference to rice, wheat, and maize in India and Odisha,
- To investigate the adaptation strategies employed by farmers in response to these impacts,
- To analyse the key factors influencing their adaptation decision-making.

Data Sources

- Secondary data on rainfall patterns and average temperature in India and Odisha are obtained from the World Bank's climate change knowledge portal for the period 1961-2017.
- Data on crop productivity of rice, wheat, and maize in India and Odisha are collected from the Food and Agriculture Organization (FAO) and Odisha agricultural statistics for the period 1970-2019.
- Primary data is gathered through structured household interviews from a random sample of 310 farm households belonging to four different categories of farmers, i.e., marginal, small, medium and large.
- The interviews are conducted in Chamakhandi and Mandiapalli villages located in Ganjam district, Odisha. A multi-stage sampling technique is employed for sample selection.

Methodology

- Ordinary Least square regression is used to estimate the impact of rainfall and temperature of the yields of rice, wheat and maize.
- **Framework of Probit model**: a rational farmer will generally employ adaptation strategies only when the net benefits of doing so outweigh the costs of not doing so (Mendelsohn, 2012).
- Although the net benefit is not directly observable, the economic agents' behaviour (in this case, the individual farmer) is observable through the decisions they make (Deressa et al., 2008).

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- Accordingly, Y_j and Y_k represent a household's benefits for two choices, which are denoted by U_j and U_k respectively.
- The linear regression models can be specified as
  - $U_j = \beta_j' X_i + \epsilon_j$ (1)
  - $U_k = \beta_k' X_i + \epsilon_k$ (2)
- "If a household decides to use option j, it follows that the perceived benefit from option j is greater than the benefit from other options (i.e. k) which can be written as
  - $U_{ij}\left(\beta_j' X_i + \epsilon_j\right) > U_{ik}(\beta_k' X_i + \epsilon_k), j \neq k$ (3)
- Where U_{ij} and U_{ik} are the perceived benefits for adaptation options j and k by ith farmer. X_i is the matrix of explanatory variables that influences the choice of the adaptation options. β_j' and β_k' are the parameters to be estimated. ϵ_j and ϵ_k are the error terms which are assumed to be independently and identically distributed.

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- The formula for MVP model for i^th observation and m^th equation is as follows (Cappellari and Jenkins, 2003; Tocco *et al*., 2013).

- $Y_{im} = 1$ if $Y_{im}^{*} > 0$ and 0 otherwise (i=1,2,….,N; m=1,2,…,M)

  - $Y_{im}^{*} = X_{im}^{*}\beta_m + \varepsilon_{im}$ (4)

- "N is the number of observations,
- M is the number of options
- X_{im} is the matrix of explanatory variables
- β_m is the matrix of parameters , and
- ε_{im} is the matrix of error terms"

Table 2 OLS regression of rice yield on rainfall and temperature in India

Rice yield	Coefficient	Standard error	t-value	p-value	Adjusted R-square value
Constant	−368406	43701.6	−8.430	2.01E-11***	0.519913
Rainfall	13.294	7.39613	1.797	0.0779*	
Temperature	15423.3	1663.81	9.27	9.33E-13***	

Table 3 OLS regression of wheat yield on rainfall and temperature in India

Wheat yield	Coefficient	Standard error	t-value	p-value	Adjusted R-square value
Constant	−349700	44140	−7.923	1.32E-10***	0.487856
Rainfall	1.90981	7.68837	0.2484	0.8048	
Temperature	14977.6	1682.9	8.9	3.58E-12***	

Table 4 OLS regression of maize yield on rainfall and temperature in India

Maize yield	Coefficient	Standard error	t-value	p-value	Adjusted R-square value
Constant	−281686	35235.7	−7.994	1.01E-10***	0.49842
Rainfall	10.9434	5.72227	1.912	0.0611*	
Temperature	11632.9	1359.47	8.557	1.26E-11***	

Table 5 OLS regression of rice yield on rainfall and temperature in Odisha

Rice yield	Coefficient	Standard error	t-value	p-value	Adjusted R-square value
Constant	−15432.9	3707.27	−4.163	1.00E-04***	0.317072
Rainfall	1.47625	0.361719	4.081	0.0002***	
Temperature	568.593	134.871	4.216	1.00E-04***	

Table 6 OLS regression of wheat yield on rainfall and temperature in Odisha

Wheat yield	Coefficient	Standard error	t-value	p-value	Adjusted R-square value
Constant	7669.95	2111.15	3.633	7.00E-04***	0.159986
Rainfall	0.129917	0.163893	0.7927	0.4319	
Temperature	−238.712	81.3277	−2.935	5.10E-03***	

Table 7 OLS regression of maize yield on rainfall and temperature in Odisha

Maize yield	Coefficient	Standard error	t-value	p-value	Adjusted R-square value
Constant	−24865.1	6161.45	−4.036	2.00E-04***	0.225397
Rainfall	1.65887	0.597084	2.778	0.0078***	
Temperature	927.749	225.032	4.123	2.00E-04***	

Figure 2 Distribution of farmer's adaptation practices in developed village

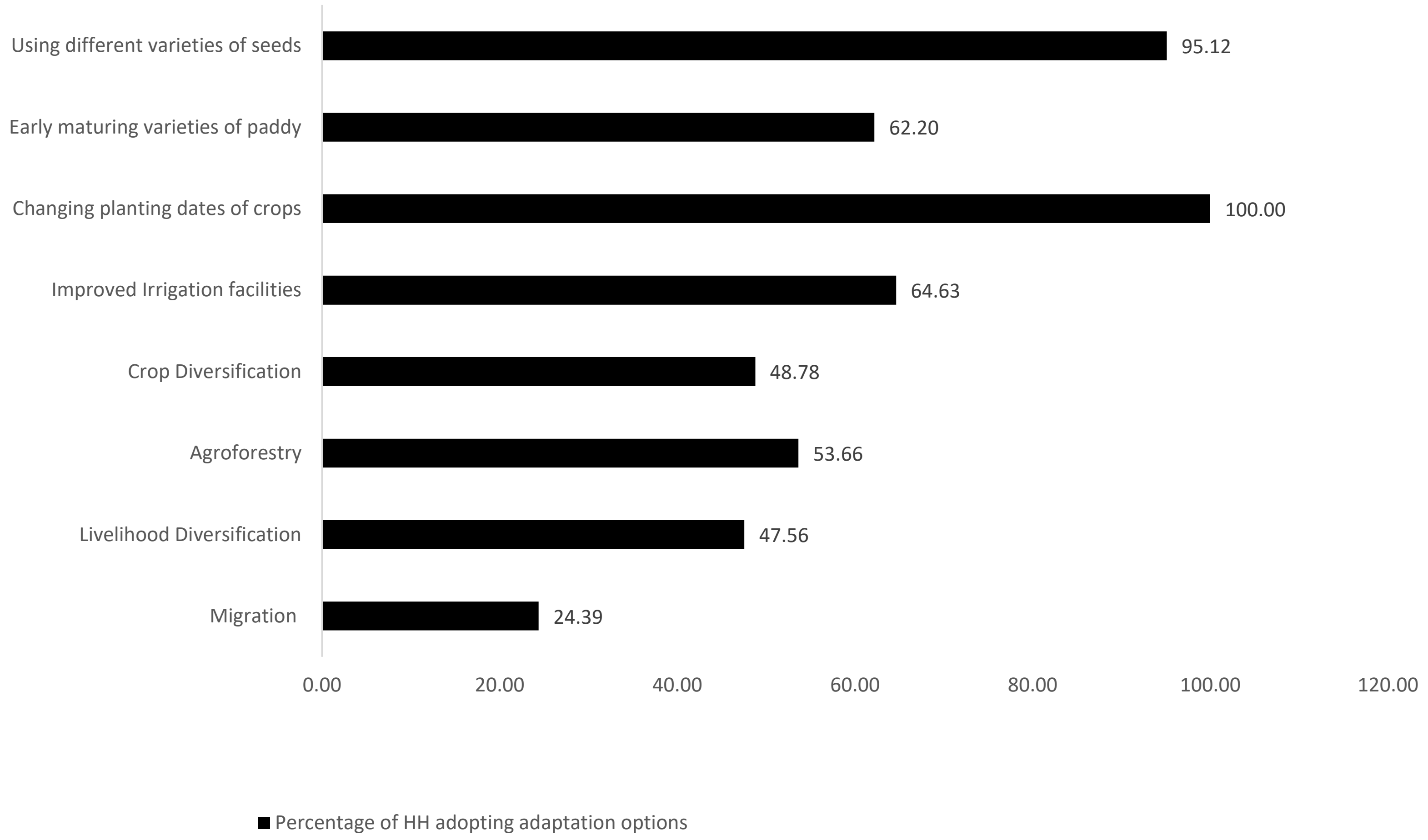
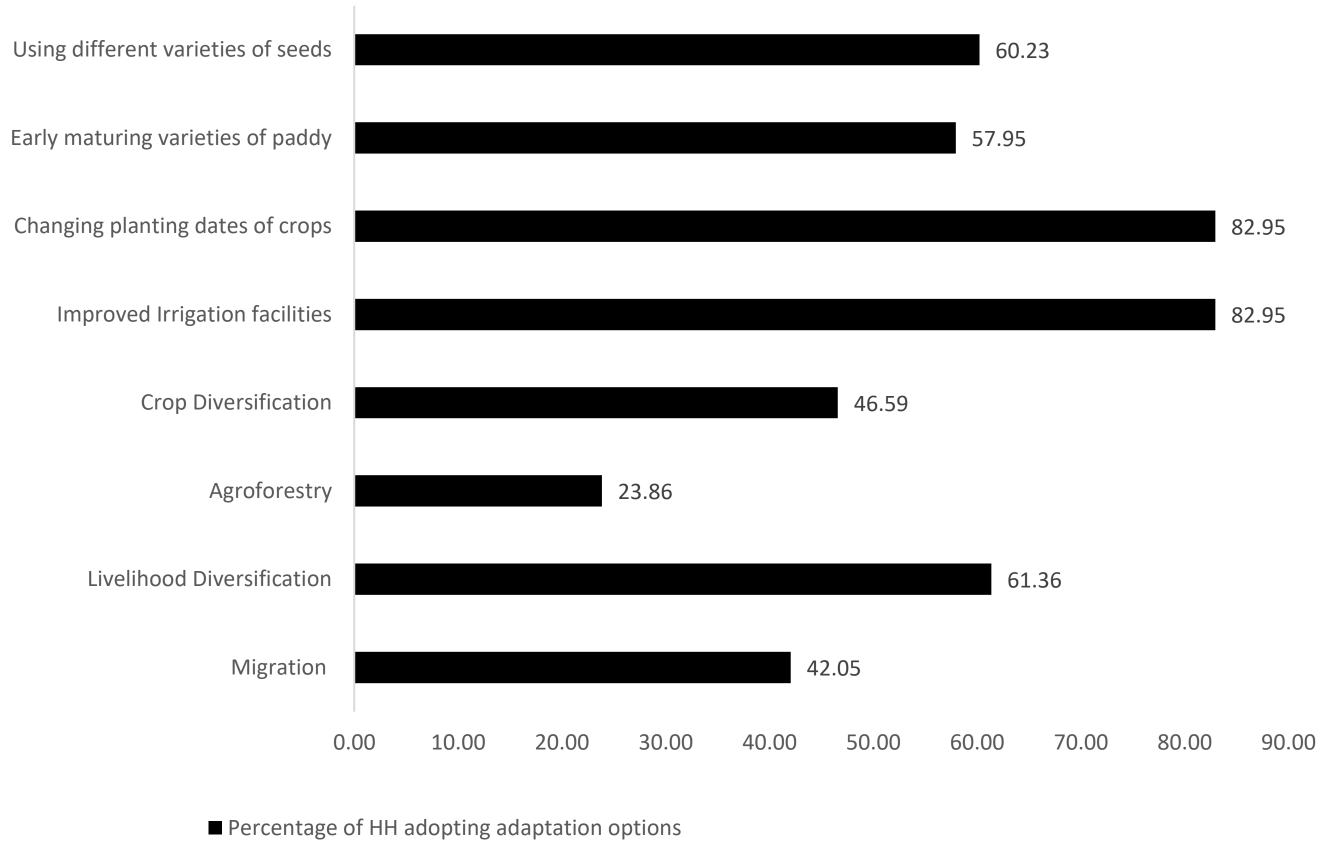


Figure 3 Distribution of farmer's adaptation practices in less developed village



Maximum likelihood estimation of farmers' adaptive practice using MVP in developed village

Explanatory Variables	Adaptation Practices							
	Different Varieties of Seeds	Early Maturing Varieties of Paddy	Changing planting dates of crops	Improved Irrigation Facilities	Crop Diversification	Agroforestry	Livelihood Diversification	Migration
Perception	-0.369 (0.519)	3.524*** (0.874)	1.103* (0.582)	3.083*** (0.549)	2.193*** (0.461)	1.857*** (0.427)	0.808 (0.519)	2.096*** (0.425)
Caste	0.093 (0.625)	2.196*** (0.755)	-0.013 (0.367)	1.916*** (0.560)	0.854** (0.371)	0.444 (0.377)	-0.014 (0.325)	0.010 (0.361)
Gender	1.597*** (0.516)	3.470*** (0.774)	2.083*** (0.313)	0.379 (0.444)	-0.491 (0.861)	0.989*** (0.358)	1.873*** (0.289)	1.908*** (0.322)
Education	2.760*** (0.732)	3.025*** (0.627)	0.997*** (0.339)	0.911*** (0.345)	1.897*** (0.363)	0.914*** (0.281)	-0.479 (0.311)	0.465 (0.362)
Occupation	2.013** (0.999)	0.444 (0.674)	0.702 (0.564)	1.935*** (0.669)	-0.336 (0.473)	-0.049 (0.459)	0.243 (0.594)	0.499 (0.402)
Access to Irrigation	3.935*** (1.034)	-1.574*** (0.563)	-0.321 (0.617)	-	-2.239*** (0.631)	-1.214** (0.559)	-0.383 (0.518)	-0.983* (0.516)
Income	-0.00002 (0.00002)	-0.00004*** (0.00002)	1.86E-06 (0.000007)	-1.8E-05 (0.00001)	-9.80E-06 (0.00001)	-0.00001 (0.000008)	-0.00001* (0.000007)	-5.6E-06 (0.000008)
Access to Credit	1.390* (0.823)	0.802 (0.493)	-0.341 (0.319)	1.360*** (0.401)	0.410 (0.330)	0.397 (0.358)	0.526* (0.296)	0.333 (0.337)
Access to Climate Information	1.648** (0.800)	0.674 (0.811)	-0.285 (0.573)	-0.126 (0.498)	1.500** (0.628)	0.695 (0.484)	0.727 (0.561)	0.087 (0.514)
Farm size	**-2.748*** (0.982)	-4.061*** (0.786)	-0.633** (0.318)	-1.764*** (0.446)	-0.586* (0.330)	-0.096 (0.397)	-0.250 (0.365)	-0.883** (0.358)
Access to Extension advice	-0.402 (0.987)	0.542 (0.584)	-0.203 (0.431)	-1.342** (0.637)	-0.626 (0.620)	0.026 (0.419)	-0.339 (0.377)	-0.790* (0.425)
Constant	-4.050*** (1.137)	-5.064*** (1.093)	-1.672*** (0.354)	-2.021*** (0.716)	-1.067 (0.893)	-2.070*** (0.344)	-1.119*** (0.351)	-1.476*** (0.308)
No of Observations	140	140	140	140	140	140	140	140
Log pseudolikelihood	-12.368	-17.303	-53.394	-25.836	-33.440	-49.118	-61.574	-51.479
Prob > chi2	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Pseudo R2	0.873	0.818	0.450	0.733	0.655	0.493	0.365	0.467

Maximum likelihood estimation of farmers' adaptive practice using MVP in less developed village

Explanatory Variables	Adaptation Practices							
	Different Varieties of Seeds	Early Maturing Varieties of Paddy	Changing planting dates of crops	Improved Irrigation Facilities	Crop Diversification	Agroforestry	Livelihood Diversification	Migration
Perception	0.338 (0.282)	0.220 (0.247)	0.399 (0.289)	1.828*** (0.270)	2.551*** (0.383)	0.294 (0.471)	8.141*** (0.743)	3.708*** (0.624)
Caste	1.489*** (0.294)	-0.021 (0.258)	-0.075 (0.274)	-0.450 (0.305)	-0.897** (0.427)	-1.791** (0.881)	-0.241 (0.440)	-0.493 (0.659)
Gender	1.151*** (0.321)	-0.410 (0.261)	-0.343 (0.262)	-0.125 (0.291)	-0.105 (0.430)	0.736 (0.630)	0.486 (0.453)	-0.445 (0.415)
Education	1.366*** (0.288)	1.480*** (0.232)	1.870*** (0.244)	1.254*** (0.240)	1.679*** (0.598)	3.201*** (0.755)	4.786*** (0.464)	1.109* (0.648)
Occupation	-	0.164 (0.251)	-0.007 (0.267)	0.166 (0.309)	0.592 (0.436)	-0.864* (0.504)	0.120 (0.474)	-0.493 (0.593)
Access to Irrigation	0.465 (0.298)	0.187 (0.221)	-0.249 (0.231)	-	1.217*** (0.429)	5.068*** (1.246)	-0.336 (0.363)	3.193*** (0.753)
Income	0.00004** (0.00002)	0.000004 (0.00001)	-0.000009 (0.00001)	0.00002 (0.00002)	-0.000008 (0.00003)	-0.00006** (0.00003)	0.0000001 (0.00002)	0.00003 (0.00003)
Access to Credit	0.107 (0.292)	-0.510** (0.236)	-0.045 (0.230)	0.222 (0.263)	-0.281 (0.387)	0.234 (0.526)	0.057 (0.362)	1.251*** (0.414)
Access to Climate Information	1.282*** (0.405)	0.081 (0.346)	0.170 (0.373)	0.257 (0.429)	0.207 (0.674)	1.120 (0.779)	0.245 (0.513)	0.488 (0.445)
Farm size	-1.139*** (0.310)	0.084 (0.254)	-0.251 (0.256)	0.115 (0.306)	-1.158*** (0.336)	0.345 (0.474)	-0.029 (0.434)	-0.763 (0.750)
Access to Extension advice	0.303 (0.286)	0.640** (0.252)	0.208 (0.231)	0.249 (0.301)	3.963*** (0.684)	-0.137 (0.498)	0.087 (0.437)	0.789 (0.497)
Constant	-4.417*** (0.678)	-1.158 (0.492)	-0.733 (0.542)	-2.300*** (0.707)	-4.605*** (0.970)	-4.664*** (1.667)	-6.451*** (0.675)	-5.756*** (1.046)
No of Observations	169	169	169	169	169	169	169	169
Log pseudo likelihood	-49.680	-90.448	-78.484	-62.843	-26.406	-14.674	-22.781	-11.966
Prob > chi2	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Pseudo R2	0.568	0.226	0.329	0.463	0.774	0.852	0.805	0.884

Conclusion and Policy Implications

- Major crops (rice, wheat and maize) are vulnerable to climate change variables (rainfall and temperature) in both India and Odisha,
- Farming communities are the worst affected due to the negative consequences of climate change. For this cause, farmers are usually adopting adaptation strategies such as using different varieties of seeds, early maturing varieties of paddy, changing planting dates of crops, improved irrigation facilities, crop diversification, agroforestry, livelihood diversification and migration.
- The study revealed that educational level of the household head is the only significant factor influencing all most specific adaptation strategies in the study areas, except strategies like livelihood diversification and migration in case of the developed village.
- Moreover, access to climate change information and extension services are the significant factors influencing the probability of adapting the negative consequences of climate change.
- In this context, therefore, this study can guide the public policy with regard to educating farm household head and increasing accessibility to climate change information and extension services which would build the resilience of farming communities by increasing productivity of crops and incomes of farmers.

THANK YOU