International Journal of Enhanced Research in Educational Development (IJERED)
ISSN: 2320-8708, Vol. 14 Issue 3, May-June, 2026

Climate Change Adaptation through Climate-Smart Agriculture: Adoption Patterns and Resilience Building in Rural Odisha, India

Aseema Biswal[1], Punyatoya Patra[2]

[1]Department of Geography, Delhi School of Economics, University of Delhi
[2]Aditi Mahavidyalaya, University of Delhi

Corresponding Author: Aseema Biswal (aseemabiswal000@gmail.com)

ABSTRACT

Climate change has emerged as a major challenge for agricultural sustainability, particularly in developing countries with still gamble of monsoon agriculture, which compels a space for climate-Smart Agriculture (CSA). This study examines the extent of CSA adoption and its contribution to livelihood resilience in East India with a case study of Garudagaon village Panchayat of Odisha. The study covered 220 sample farming individual respondents across eleven villages through a structured household survey. Several indexes like Climate Awareness Index (CAI), Infrastructure Access Index (IAI), Climate-Smart Agriculture Adoption Index (CSAAI), and Climate-Smart Agricultural Resilience Index (CSARI) were developed to assess awareness, adoption and resilience. Pearson's correlation and multiple linear regression were employed for statistical analysis. The results reveal considerable spatial variation in CSA adoption among villages. Education demonstrated the strongest positive association with CSA adoption. The study also reveals a strong positive relationship between CSA adoption and livelihood resilience. Villages demonstrating higher levels of climate-smart interventions showed greater income stability and enhanced adaptive capacity. The study highlights the need for location-specific extension services and institutional strengthening to achieve sustainability through agricultural transformation at the grassroots level.

Keywords: Climate-Smart Agriculture, Climate Change Adaptation, Rural Livelihoods, Odisha, Geography

INTRODUCTION

Agriculture still forms the foundation of rural livelihoods in India, supporting food security, employment and socio-economic pillar. However, it is disproportionately getting exposed to the adverse effects of climate change, including temperature uncertainty, erratic monsoon, dry spells and extreme weather events. Eastern India, being no exception to this trend and with predominantly monsoon dependent agrarian economy and smallholder farmers with limited resources to respond effectively, has become extremely vulnerable to the emerging conditions (Vermeulen et al., 2012; Thornton & Herrero, 2015; IPCC, 2023). Such stressed situation further deteriorates household income, food security and rural sustainability. Consequently, resilient agriculture has become essential requirement for achieving sustainable development goal.

The term Climate-Smart Agriculture was introduced by the Food and Agriculture Organization as an integrated approach that simultaneously seeks to increase productivity, enhance adaptation, and mitigate agricultural emissions (FAO, 2013; Lipper et al., 2014). It promotes a range of smart practices such as crop diversification, micro irrigation, integrated pest management, agroforestry etc (Rosenstock et al., 2019). Past researches have demonstrated effectiveness of CSA in ensuring climate resilience in food production system (Lipper et al., 2014; Makate et al., 2019; Jamil et al., 2021; Ma, 2024). The smart practices vary spatially due to spatial variations in physical-socio-economic conditions and characteristics. Despite of a large number of studies focusing on CSA at regional and national scales, empirical evidence at in micro-level local studies are limited, where adaptation decisions are actually implemented, to address which, this study investigates into CSA adoption in Garudagaon village Panchayat and evaluates their contribution to farmer resilience under changing climatic scenario.

STUDY AREA

The study is conducted in Garudagaon villlage Panchayat (figure 1), located in the Tangi - choudwar Block of Cuttack district of Odisha, India, lieing between approximately 20°09′ to 20°53′ North latitude and 85°41′ to 86°06′ East longitude. It consists of 11 villages, i.e.- Biswali, Chandanpur, Garudagaon, Haladibasanta, Kakatapur, Kanhupur, Kusupara, Napatua, Patalasingada, Sapanapur, and Tulasipur. It is characterized by predominantly agrarian economy where farming constitutes the primary rural occupation. The landscape consists largely of cultivated land and agriculture is dominated by paddy with while pulses and vegetables grown as secondary crops. It enjoys a tropical monsoon climate and dependence on monsoon makes agriculture highly sensitive to variations in rainfall timing and intensity. With the dominance of small holding farmers, facing constraints related to irrigation, agricultural inputs and institutional support, the Panchayat stands suitable for examining the role of climate-smart agricultural practices in enhancing adaptive capacity and resilience.

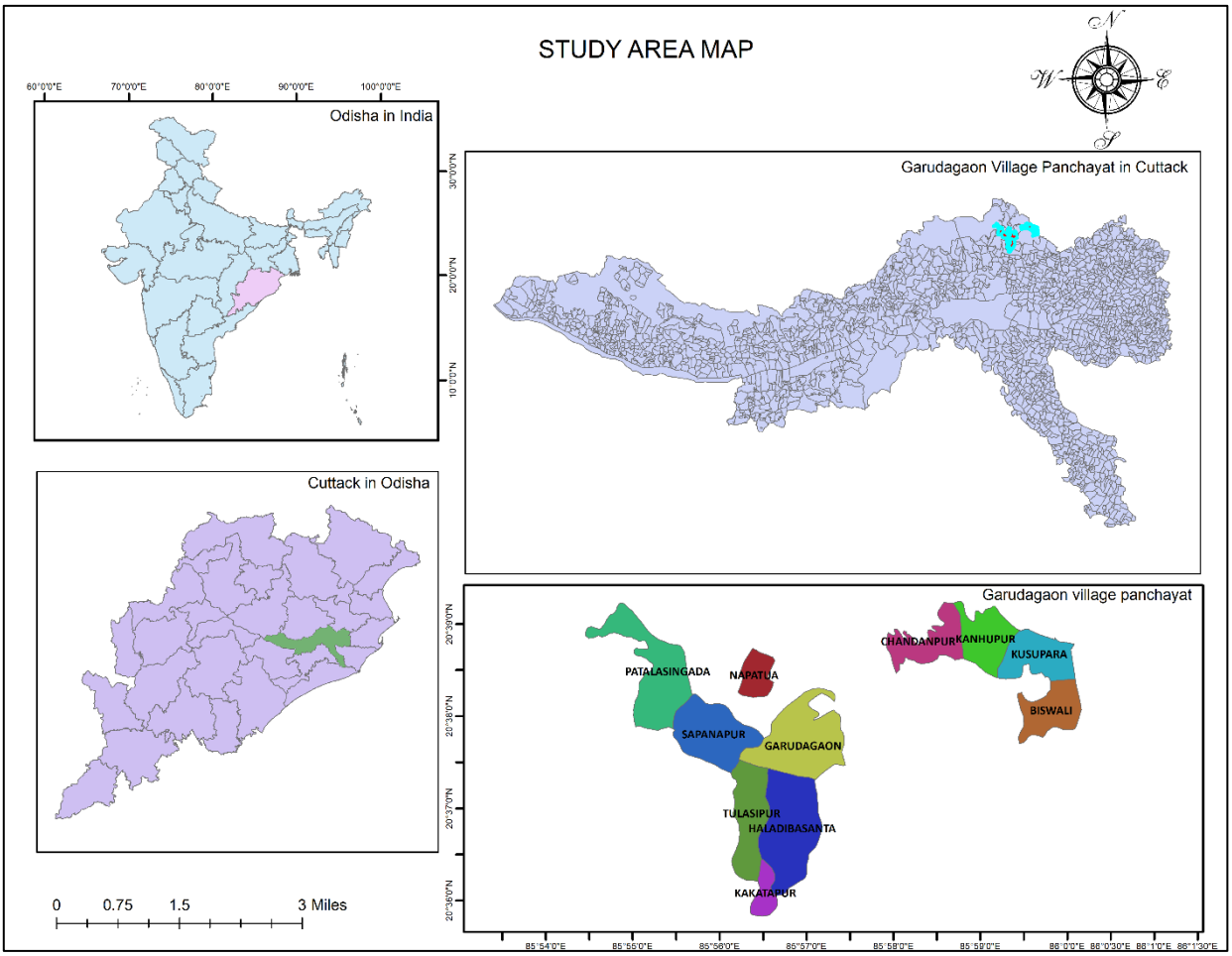

Fig.1: Study Area Map

DATA AND METHODOLOGY

Dataset:
The study utilized both primary and secondary sources of information. Primary data were collected from 220 farming individual respondents based on random sampling through a structured questionnaire. Twenty households were selected from each of the eleven villages using random sampling after having informed consent and a structured questionnaire survey was conducted for data collection regarding educational attainment, farm size, agricultural practices, climate perception, access to extension services, CSA adoption, agricultural income etc. Secondary data was obtained from government reports, census publications and published research papers.

Climate Awareness Index (CAI):
The index ranged from 1 to 5, with higher values indicating greater awareness regarding climate change and its agricultural implications. This index was measured by using response to five statements, i.e.- changing rainfall patterns, changing temperature pattern, extreme climatic event occurrence, climate impacts on crop production and future climate risks, recorded on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5).

$$CAI = (C_1 + C_2 + C_3 + C_4 + C_5)/5$$

Infrastructure Access Index (IAI):
The index ranged from 0 to 5. Infrastructure access was assessed using five indicators, i.e.- irrigation access, smartphone ownership, internet connectivity, access to weather information and market information, each facility assigned score 1 and non-availability 0.

$$IAI = I_1 + I_2 + I_3 + I_4 + I_5$$

Climate-Smart Agriculture Adoption Index (CSAAI):
The index ranged from 0 to 1, evaluated through eight indicators, i.e.- crop diversification, improved seed varieties, integrated nutrient management, integrated pest management, water conservation practices, efficient irrigation, agroforestry, and organic farming, each with a score of 1.

$$CSAAI = (A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8)/8$$

Climate-Smart Agricultural Resilience Index (CSARI):
The index ranged from 4 to 20, assessed through four likert scale measuring 4 factors, i.e.- capacity to maintain crop production, ability to cope with irregular weather, ability to recover from climatic shocks and confidence regarding future farming.

$$CSARI = R_1 + R_2 + R_3 + R_4$$

Statistical Analysis:
Pearson's correlation analysis was employed to examine the relationship between CSAAI and independent variables like age, education, farming experience, farm size, farm income, climate awareness and infrastructure access.

Multiple linear regression was also applied to identify the determinants of agricultural resilience, with CSARI as dependent variable and rest variables and CSAAI as independent variables, using the following formula:

$$CSARI = \beta 0 + \beta 1 Age + \beta 2 Education + \beta 3 Experience + \beta 4 FarmSize + \beta 5 FarmIncome + \beta 6 CAI + \beta 7 IAI + \beta 8 CSAA$$

The overall methodology has been presented in figure 2.

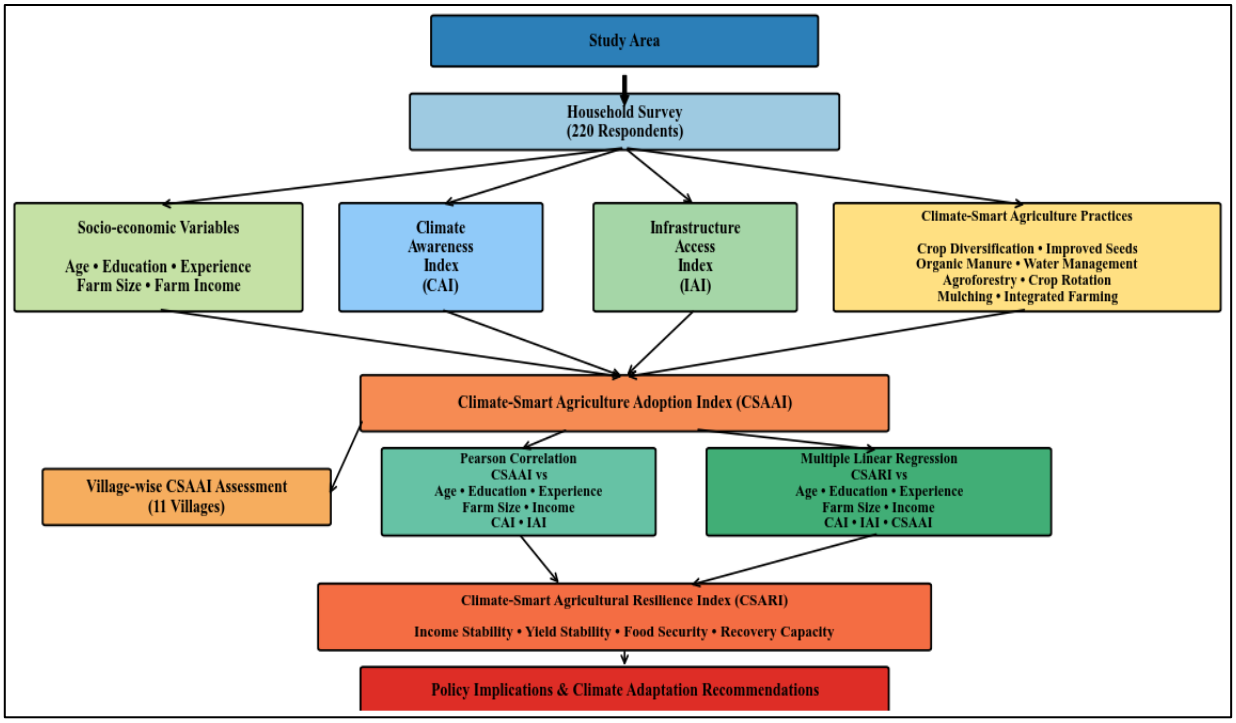

Fig.2: Methodology Flowchart

RESULTS AND DISCUSSION

Village-wise Pattern of CSA Adoption:
The village-level analysis (figure 3) revealed considerable variation in climate-smart agriculture adoption across the Gram Panchayat. Patalasingada recorded the highest average CSAAI value (0.738), followed by Garudagaon (0.675) and Napatua (0.656), while Kanhupur exhibited the lowest score (0.537), Sapanapur (0.575) and both Biswali and Chandanpur (0.594). The findings show the spatially variability CSA adoption that may be ascribed to differences in resource availability, farmer awareness, social and institutional framework.

Correlation Analysis:
Pearson's correlation analysis (figure 3) revealed that education exhibited moderate positive correlation with CSA adoption ($r = 0.402$, $p < 0.001$), suggesting that educated farmers implement climate-smart farming techniques better. This also highlights the significance of human capital in promoting agricultural innovation. Farm income also showed a weak positive relationship with CSA adoption ($r = 0.175$), indicating that rich households may invest more in CSA practices. Age ($r = 0.155$), farming experience ($r = 0.151$), and infrastructure access ($r = 0.149$), farm size ($r = 0.119$) also displayed weak positive relationships with CSA adoption. Climate awareness demonstrated a very weak, though positive relationship with CSA adoption ($r = 0.068$), indicating that awareness alone may not necessarily translate into behavioural change unless supported by socio- economic- technical resources.

Climate-Smart Agricultural Resilience
The multiple regression analysis (figure 3) produced a coefficient of determination (R^2) of 0.831, being statistically significant ($p < 0.001$), meaning that approximately 83.1 percent of the variation in CSA resilience among surveyed households can be explained by the selected independent variables. Among all independent variables, CSAAI emerged as the most influential factor ($\beta = 8.032$, $p < 0.001$), suggesting that farmers adopting a greater number of CSA practices exhibited substantially higher resilience to climatic stresses. Farm size ($\beta = 0.081$, $p = 0.068$), farm income ($\beta = 8.21 \times 10^{-7}$, $p = 0.061$), and Infrastructure Access Index ($\beta = 0.097$, $p = 0.058$) showed positive but less significant effects. In contrast, age ($\beta = -0.017$, $p = 0.435$), education ($\beta = 0.007$, $p = 0.550$), farming experience ($\beta = 0.014$, $p = 0.496$), and Climate Awareness Index ($\beta = 0.209$, $p = 0.114$) did not show statistically significant result. Hence, the adoption of CSA practices remains the primary driver of resilience, confirming with previous studies (Aryal et al., 2018; Diro et al., 2022), highlighting the importance of promoting CSA interventions for strengthening adaption to climate change. The findings argue that CSARI is not determined by a single factor, rather from the interaction of many factors.

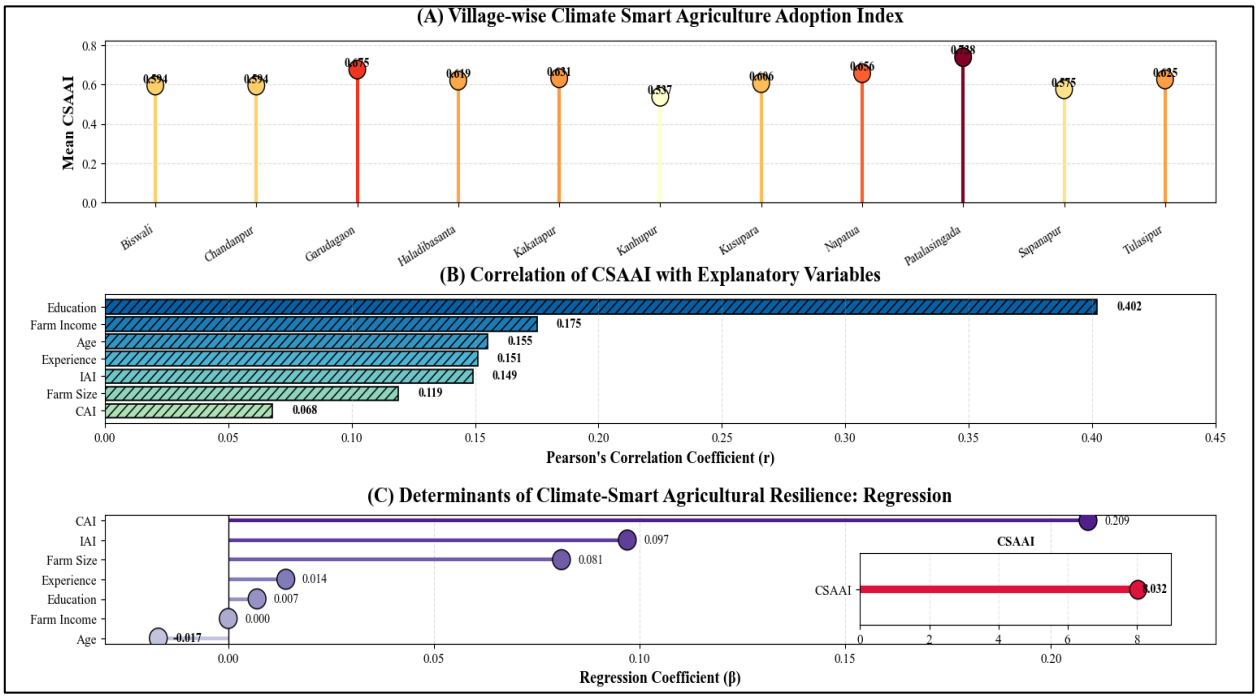

Fig.3: Results of Analysis

From policy perspective, more emphasis should be placed on expanding CSA interventions through village-level extension programmes, farmer field schools, irrigation facilities, improving access to climate information services and promoting digital agricultural advisory systems etc (Makate et al., 2019; Tripathi & Mishra, 2017; Khatri-Chhetri et al., 2020; Kangogo et al., 2021). Financial assistance, input subsidies and efficient institutional support may strengthen

households to adopt CSA practices and special attention should be given to lower adopters through targeted capacity-building programmes and locally tailored adaptation strategies.

CONCLUSION

This study examined climate-smart agriculture adoption and agricultural resilience among farming households in Garudagaon village Panchayat as a case study to East Indian scenario. The findings revealed moderate to high adoption of climate-smart agricultural practices, with variation across villages. Education emerged as the most significant factor associated with CSA adoption. Adoption of climate-smart practices is the major driver of farmers' resilience against climate change. Future policy interventions should prioritise awareness, education, capacity building to enhance agricultural resilience in rural Odisha. Building climate resilience requires an integrated approach with farmer participation for attaining sustainable development goals at grassroot level.

REFERENCES

[1] Abegunde, V. O., Sibanda, M., & Obi, A. (2019). The dynamics of climate change adaptation in sub-Saharan Africa. *Sustainability*, 11(4), 1250. https://doi.org/10.3390/su11041250

[2] Aryal, J. P., Rahut, D. B., Maharjan, S., & Erenstein, O. (2018). Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. *Natural Resources Forum*, 42(3), 141–158. https://doi.org/10.1111/1477-8947.12152

[3] Aryal, J. P., Farnworth, C. R., Khurana, R., et al. (2020). Does women's participation in agricultural technology adoption decisions affect the adoption of climate-smart agriculture? *Review of Development Economics*, 24(3), 973–990. https://doi.org/10.1111/rode.12670

[4] Diro, S., Tesfaye, A., & Erko, B. (2022). Determinants of adoption of climate-smart agricultural technologies and practices. *Agriculture & Food Security*, 11, 85. https://doi.org/10.1186/s40066-022-00385-2

[5] FAO. (2013). *Climate-Smart Agriculture Sourcebook*. Rome: Food and Agriculture Organization.

[6] IPCC. (2023). *Climate Change 2023: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change.

[7] Jamil, I., Jun, W., Mughal, B., et al. (2021). Does adaptation of climate-smart agricultural practices increase farmers' resilience to climate change? *Environmental Science and Pollution Research*, 28, 27238–27249. https://doi.org/10.1007/s11356-021-12425-8

[8] Kangogo, D., Dentoni, D., & Bijman, J. (2021). Adoption of climate-smart agriculture among smallholder farmers. *Land Use Policy*, 109, 105666. https://doi.org/10.1016/j.landusepol.2021.105666

[9] Khatri-Chhetri, A., Regmi, P. P., Chanana, N., & Aggarwal, P. K. (2020). Potential of climate-smart agriculture in reducing women farmers' drudgery. *Climatic Change*, 158, 29–42. https://doi.org/10.1007/s10584-018-2350-8

[10] Lipper, L., Thornton, P., Campbell, B. M., et al. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, 4(12), 1068–1072. https://doi.org/10.1038/nclimate2437

[11] Ma, W. (2024). Climate-smart agriculture: Adoption, impacts, and implications for sustainable development. *Mitigation and Adaptation Strategies for Global Change*, 29. https://doi.org/10.1007/s11027-024-10139-z

[12] Makate, C., Makate, M., Mango, N., & Siziba, S. (2019). Increasing resilience of smallholder farmers through multiple adoption of climate-smart agriculture innovations. *Journal of Environmental Management*, 231, 858–868. https://doi.org/10.1016/j.jenvman.2018.10.069

[13] Rosenstock, T. S., Lamanna, C., Chesterman, S., Bell, P., Arslan, A., Richards, M., et al. (2019). When less is more. *Environmental Research Letters*, 14(12), 125010. https://doi.org/10.1088/1748-9326/ab5cf8

[14] Thornton, P. K., & Herrero, M. (2015). Adapting to climate change in agricultural systems. *Nature Climate Change*, 5(4), 304–306. https://doi.org/10.1038/nclimate2628

[15] Tripathi, A., & Mishra, A. K. (2017). Knowledge and passive adaptation to climate change: An example from Indian farmers. *Ecological Economics*, 122, 105–114. https://doi.org/10.1016/j.ecolecon.2015.11.002

[16] Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate change and food systems. *Annual Review of Environment and Resources*, 37, 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

[17] Wossen, T., Berger, T., Mequaninte, T., & Alamirew, B. (2017). Climate variability, consumption risk and poverty in rural Ethiopia. *Environment and Development Economics*, 22(3), 297–318. https://doi.org/10.1017/S1355770X16000476