

Climate Smart Agriculture Adaptation Resource Inequalities Among Smallholder Farmers in the Barind Tract of Bangladesh: The Role of Governance Inclusion and Institutional Access

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ABSTRACT: Climate-smart agriculture (CSA) is increasingly discussed as an approach for responding to climate risks while supporting agricultural productivity, resilience and sustainable resource use. However, access to the institutional and governance resources that enable farmers to adopt CSA may be uneven. This manuscript develops an empirical framework for examining adaptation-resource inequalities among smallholder farmers in the drought-prone Barind Tract of Bangladesh, with particular attention to governance inclusion and institutional access. The study is aligned with an approved doctoral research design focused on CSA adoption and its contribution to livelihood resilience in Rajshahi, Naogaon and Chapainawabganj. A mixed-methods design will combine a structured household survey, GPS-based spatial information, key-informant interviews, focused ethnographic fieldwork, policy and institutional document review, and relevant secondary data. The quantitative component will construct a Climate-Smart Agriculture Adoption Index (CSAAI) and examine socioeconomic, livelihood-capital, institutional, environmental and behavioural determinants using a Fractional Logit model. The institutional component will examine stakeholder roles, financing, extension, policy implementation and barriers through stakeholder mapping, a Power–Interest Matrix, a Barrier Severity Index and thematic analysis. Governance inclusion and institutional access will therefore be treated as mechanisms and explanatory conditions within the broader CSA adoption framework rather than as unsupported outcome measures. The manuscript does not report empirical results because the household survey and fieldwork are scheduled for the subsequent fieldwork phase of the doctoral project. This design provides a transparent basis for assessing whether differences in institutional access and governance inclusion are associated with unequal opportunities to adopt CSA and, subsequently, with livelihood resilience.

KEYWORDS: Climate-smart agriculture; adaptation resources; Barind Tract; smallholder farmers; governance inclusion; institutional access; livelihood resilience; Bangladesh

I. INTRODUCTION

Climate change creates uneven risks for agricultural households because exposure to climatic hazards interacts with livelihood assets, institutional conditions and the capacity to obtain and use resources. The Intergovernmental Panel on Climate Change identifies adaptive capacity, exposure and vulnerability as interconnected dimensions of climate risk, while adaptation research increasingly examines the institutional and social conditions through which adaptation becomes possible. In agricultural systems, these conditions include access to information, extension, finance, technologies, infrastructure and collective institutions.

Climate-smart agriculture (CSA) is commonly framed around three broad objectives: sustainably increasing productivity and incomes, strengthening resilience and adaptation to climate change, and, where possible, reducing or avoiding greenhouse-gas emissions. At the same time, CSA is not a single technology or universally transferable package. Scholarship has highlighted conceptual, political and distributional debates concerning who defines CSA, whose interests are prioritised, and whether apparently

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beneficial interventions distribute costs and benefits equitably (Taylor, 2018; Newell & Taylor, 2018; Rosén et al., 2018; Clapp et al., 2018). These debates make institutional access important when examining CSA adoption among resource-constrained farmers.

The Barind Tract of northwestern Bangladesh provides an important setting for such an analysis. The approved doctoral study focuses on Rajshahi, Naogaon and Chapainawabganj, where agricultural livelihoods are exposed to recurrent drought, rainfall variability, high temperatures and dry-season water constraints. Recent evidence has documented substantial drought vulnerability and livelihood implications in the Barind region (Afrin et al., 2024; Tahasin et al., 2024). The region therefore provides a relevant context for examining how farmers' livelihood capitals and institutional environments shape responses to climate stress.

Access to adaptation-related resources is multidimensional. Farmers may need climate information and early warning, agricultural extension, finance, water-management support, technologies, market information, government programmes and social or community networks. Possession of a livelihood asset does not necessarily translate into access to institutional programmes, and formal programme availability does not necessarily mean that farmers can effectively use the service. Information gaps, administrative requirements, limited outreach, institutional trust and local power relations may influence whether households are reached and able to participate.

Against this background, this manuscript focuses on adaptation-resource inequalities as an analytical lens within the approved doctoral research. It does not replace the doctoral study's central question concerning CSA adoption and livelihood resilience. Rather, governance inclusion and institutional access are examined as institutional dimensions that may help explain differences in farmers' opportunities to adopt CSA. The Sustainable Livelihood Framework (SLF) provides the broader analytical structure by connecting human, natural, financial, physical and social capital with institutional and environmental conditions (Scoones, 1998; DFID, 1999).

The manuscript has three analytical aims: first, to examine the institutional and resource conditions surrounding CSA adoption among smallholder farmers in the Barind Tract; second, to assess how governance and institutional factors are represented in the explanation of CSA adoption; and third, to identify institutional, policy, financing and implementation barriers that may constrain the scaling of CSA. These aims are operationalised through the approved doctoral methodology, which combines household-level quantitative analysis with stakeholder, qualitative and documentary evidence.

II. LITERATURE REVIEW

A. Climate-Smart Agriculture and Adaptation Resources

CSA adoption is influenced by more than farmers' awareness of climate risks. Reviews of CSA adoption identify socioeconomic, institutional, environmental, financial and informational factors as recurring determinants, while also emphasising substantial heterogeneity across contexts (Ma & Rahut, 2024; Finizola e Silva et al., 2024). Recent reviews further show that CSA practices may affect productivity, income, resilience and greenhouse-gas outcomes through context-specific pathways rather than through a uniform package of interventions (Lou et al., 2024; Zheng et al., 2024).

In the Bangladesh context, evidence on CSA includes work on climate-resilient agricultural practices and their implications for food security and livelihoods. Chaki et al. (2023) document a range of CSA technologies and practices relevant to Bangladesh. Recent empirical work also indicates that adaptation can be associated with multidimensional livelihood outcomes, although the direction and magnitude of these relationships depend on local ecological and socioeconomic conditions (Islam & Farjana, 2024).

These findings support an analytical distinction between adoption of a practice and access to the resources required to adopt it. A household may have a positive attitude toward a practice but lack finance, extension, information, irrigation capacity or institutional support. Consequently, adaptation-resource inequality can be treated as part of the enabling environment for CSA rather than as a substitute for measuring CSA adoption itself.

B. Governance Inclusion and Institutional Access

Institutional access includes more than geographic proximity to an organisation. For agricultural households, it can encompass awareness of available services, ability to meet programme requirements, contact with extension providers, access to information, participation in collective processes, trust in institutions and the practical usability of services. Governance inclusion similarly concerns whether farmers are informed, heard and considered in institutional processes affecting resource allocation and agricultural support.

Climate adaptation scholarship has increasingly emphasised that adaptation is shaped by institutional arrangements and by the distribution of decision-making power and resources. This is particularly relevant to CSA because the capacity to adopt a practice can depend on programmes, extension systems, credit, infrastructure and local coordination. The approved doctoral proposal therefore treats institutional variables alongside livelihood-capital, environmental and behavioural variables when examining determinants of CSA adoption.

An important implication is that governance should not be assumed to cause adoption merely because households report positive institutional experiences. Cross-sectional data can identify associations but cannot by themselves establish temporal direction. The

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empirical analysis should therefore distinguish measured associations from causal claims and use qualitative evidence to examine the processes through which institutional relationships may facilitate or constrain adoption.

C. The Barind Tract Context

The Barind Tract is a drought-prone agricultural landscape in northwestern Bangladesh. Research on the region documents drought vulnerability and livelihood effects, including the significance of water availability and agricultural dependence (Afrin et al., 2024; Tahasin et al., 2024). Rainwater harvesting and integrated water-resource management have also been examined as relevant responses in drought-prone Barind environments (Rahaman et al., 2019).

These conditions make the region appropriate for investigating how environmental stress interacts with livelihood resources and institutional support. However, evidence should not be generalised automatically from other Bangladesh contexts, particularly coastal settings, because the hazard profile, water regime, production systems and institutional challenges differ.

III. CONCEPTUAL FRAMEWORK

The study uses the Sustainable Livelihood Framework as its primary organising framework. The SLF considers livelihood outcomes in relation to five forms of capital—human, natural, financial, physical and social—within a wider vulnerability and institutional context (Scoones, 1998; DFID, 1999). For the present manuscript, climate stress represents part of the vulnerability context, while governance inclusion and institutional access are treated as institutional conditions that shape farmers' ability to obtain and use adaptation-related resources.

The conceptual pathway is therefore: climate and environmental stress → livelihood exposure and perceived need for adaptation → access to institutional and livelihood resources → CSA adoption decisions and combinations of practices → livelihood resilience and adaptation outcomes. Governance inclusion and institutional access may operate both directly, by facilitating information, services and support, and indirectly, by strengthening farmers' ability to mobilise other livelihood capitals.

The framework deliberately avoids treating institutional access as a guaranteed determinant. Its empirical role will be assessed using the household survey and qualitative evidence. The household survey will provide measurable indicators of institutional contact and support, while KIIs, focused ethnographic fieldwork and policy-document analysis will examine how institutional processes operate in practice. This combination is intended to distinguish formal availability of support from farmers' actual experience of access and participation.

IV. MATERIALS AND METHODS

A. Study Area and Target Population

The study focuses on the Barind Tract of Bangladesh, with empirical attention to Rajshahi, Naogaon and Chapainawabganj. These districts form the core empirical area identified in the approved doctoral proposal. The target population comprises farming households whose livelihoods are substantially connected with agriculture and related activities. Primary respondents will be household heads or adult household members directly involved in agricultural decision-making.

The study-area description will be supported during the empirical phase by relevant secondary data. In accordance with the approved methodological design, biophysical evidence will be integrated from appropriate authoritative sources, including Bangladesh Meteorological Department (BMD) data for rainfall and temperature, Bangladesh Water Development Board (BWDB) information for groundwater and water conditions, and Soil Resources Development Institute (SRDI) information for soil characteristics, where available and appropriate.

B. Research Design and Data Collection

The approved doctoral research uses a mixed-methods design. Primary quantitative data will be collected through a structured household survey. Qualitative and institutional evidence will be generated through key-informant interviews (KIIs), focused ethnographic fieldwork involving participant observation and informal conversations, and relevant policy and institutional documents. Secondary agricultural, climate, policy and institutional data will be used to complement the primary evidence.

The approved proposal initially targets approximately 400 farming households, with the final sample and field sites subject to the approved protocol, sampling-frame availability, field conditions and supervisory consultation. The sampling strategy is designed to capture variation across the selected Barind districts rather than to claim national representativeness.

The questionnaire will capture household characteristics, livelihood capitals, agricultural practices, climate-related conditions, institutional contacts, access to extension and information, financial and other support, barriers to CSA adoption, and outcomes relevant to livelihood resilience. GPS coordinates will be collected where ethically and operationally appropriate to support spatial analysis. KIIs will focus on stakeholder roles, institutional arrangements, policy implementation, financing, extension, barriers and opportunities for CSA scaling.

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C. Operationalisation of CSA Adoption

The principal adoption measure will be the Climate-Smart Agriculture Adoption Index (CSAAI) specified in the approved doctoral proposal. The index will represent the proportion of CSA practices adopted by a farmer from the set of practices included in the study, with practice intensity incorporated where defined in the final instrument. The index will be bounded between 0 and 1. The exact practice list and scoring rules will be finalised through questionnaire development and pilot testing rather than assumed in advance.

Descriptive statistics will summarise the prevalence of individual CSA practices and overall adoption. GIS will be used to examine spatial patterns, and Moran's I will be used to assess spatial autocorrelation where the final spatial data permit such analysis.

D. Institutional and Governance Variables

Institutional access will be operationalised using survey indicators concerning contact with agricultural extension, access to climate and agricultural information, participation in relevant government or other programmes, access to finance and institutional support, and reported barriers to obtaining services. Governance-related indicators will focus on observable or reportable dimensions such as information transparency, responsiveness, fairness in beneficiary selection, participation and trust, subject to validation during instrument development.

These variables will not be combined into a new outcome index unless the final questionnaire, reliability assessment and supervisor review support such construction. This is an intentional departure from the attached manuscript's Adaptation Resource Access Index because that index is not part of the approved doctoral analytical framework. The revised manuscript therefore avoids presenting an unapproved composite measure as an established result.

E. Analytical Strategy

Objective 1 of the doctoral study will use descriptive statistics, CSAAI construction, GIS and spatial analysis to assess the level and distribution of CSA adoption. Objective 2 will examine socioeconomic, institutional, environmental, behavioural and livelihood-capital determinants. Because the CSAAI is bounded between 0 and 1, the approved proposal specifies a Fractional Logit Regression Model with marginal effects.

Objective 3 will focus directly on the institutional dimension developed in this manuscript. Stakeholders involved in CSA promotion and implementation will be identified and examined through stakeholder mapping and a Power–Interest Matrix. A Barrier Severity Index will be developed to assess technological, economic, institutional, environmental and policy barriers. KIIs, focused ethnographic evidence and policy documents will be analysed thematically to identify institutional challenges, financing gaps, policy bottlenecks and implementation processes.

Objective 4 will assess the contribution of CSA adoption to livelihood resilience and climate-change adaptation capacity through a Livelihood Resilience Index. Principal Component Analysis will be used to derive objective weights, followed by Propensity Score Matching to compare adopters and non-adopters with similar observable characteristics. The Average Treatment Effect on the Treated will be estimated for the specified livelihood and adaptation outcomes. These estimates will be interpreted cautiously because cross-sectional matching cannot remove bias from unobserved characteristics.

Quantitative and qualitative findings will be triangulated. The purpose of triangulation is not to force agreement among data sources but to examine whether survey patterns, institutional accounts, field observations and documentary evidence provide convergent, complementary or divergent explanations.

F. Ethics and Data Management

Participation will be voluntary and based on informed consent. The study will protect confidentiality and use anonymised or pseudonymised data for analysis and reporting. Access to identifiable research data will be restricted to the researcher and, where required, the supervisor or authorised research team. Digital data will be stored using password-protected and/or encrypted institutional storage. Audio recordings, where used, will be retained only as needed for transcription and verification and then deleted in accordance with the approved data-management procedure.

V. EXPECTED ANALYTICAL CONTRIBUTION

The revised manuscript is designed to make three connected contributions. First, it places institutional access within a broader empirical analysis of CSA adoption rather than treating technology uptake as an isolated household decision. Second, it examines governance inclusion through measurable household-level indicators and stakeholder/qualitative evidence, allowing institutional processes to be connected to adoption constraints. Third, it links the institutional analysis to the wider doctoral objective of understanding whether CSA adoption contributes to livelihood resilience.

An important contribution is therefore methodological: adaptation-resource inequality is treated as a mechanism and context surrounding CSA adoption, while CSA adoption remains the principal empirical outcome in the approved doctoral design. This

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preserves consistency between the manuscript and the doctoral proposal and avoids creating a separate empirical research programme unsupported by the approved protocol.

VI. LIMITATIONS

The manuscript is based on an approved research design rather than completed empirical fieldwork. Accordingly, it does not report observed household statistics, regression coefficients, spatial clusters or institutional rankings. These will only be reported after data collection, cleaning and analysis have been completed.

The planned cross-sectional design will limit strong causal interpretation of institutional variables and CSA adoption. Propensity Score Matching in the broader doctoral study can reduce imbalance on observed covariates but cannot eliminate unobserved selection bias. Self-reported measures may also be affected by recall and response bias. Spatial and institutional findings will be interpreted within the Barind study area and not assumed to represent all agricultural regions of Bangladesh.

VII. CONCLUSION

The proposed analysis examines adaptation-resource inequalities as an institutional dimension of CSA adoption among smallholder farmers in the Barind Tract. Consistent with the approved doctoral proposal, the study combines the Sustainable Livelihood Framework, household-level CSA adoption measurement, spatial analysis, stakeholder assessment, qualitative inquiry and econometric analysis. Governance inclusion and institutional access are positioned as potentially important conditions shaping farmers' ability to obtain information, services, finance and other resources relevant to CSA adoption. The empirical phase will determine the strength and nature of these relationships. Until that evidence is collected and analysed, no empirical claims about the prevalence, magnitude or statistical significance of adaptation-resource inequalities are made.

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