Reconfiguring Collective Practices as Pathways to Climate Adaptation in Tidal Coastal Agriculture of Rokan Hilir

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Abstract. Tidal coastal agriculture increasingly operates under recurrent climate related disruptions that make farming continuity dependent on collective coordination rather than household strategies alone. This study examines how collective practices are reconfigured into climate risk management pathways in three farming communities in Rokan Hilir Regency Indonesia Mukti Jaya Teluk Piyai and Raja Bejamu. Using a qualitative comparative case study design based on semi structured interviews field observations and document review the analysis integrates adaptation pathways thinking with Ostromian institutional design principles to explain divergent trajectories under broadly similar climate exposure. The results show that farming coordination is shaped by compounding risks including dry season water scarcity rainy season flooding and waterlogging cross plot pest dynamics and rising production costs. Across cases adaptation is sustained through bundles of collective practices encompassing water governance collective maintenance synchronized timing coordination routines and compliance mechanisms. These bundles evolve over time through reconfiguration involving changes in practice composition timing sequencing role distribution and enforcement arrangements. Cross case comparison identifies three distinct adaptation pathways. Mukti Jaya follows an institutionalized collective action pathway characterized by consolidated and enforceable synchronized routines. Teluk Piyai follows an incremental coping adaptation pathway shaped by seasonal and salinity constraints. Raja Bejamu follows a fragmented collective action pathway under contested scarcity. Pathway divergence is explained by interacting drivers of co- ordination feasibility enforcement capacity and ecological constraint regimes. The study advances a reconfiguration lens for pathway-based adaptation and highlights institutional trade-offs relevant for climate adaptation policy in inter- dependent coastal farming systems.

Keywords: Climate adaptation pathways, collective action, institutional reconfiguration, tidal coastal agriculture, climate risk governance.

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1 Introduction

Coastal agriculture is increasingly shaped by risk rather than season. Across low-lying deltas, farming is no longer governed primarily by predictable seasonal cycles but by uncertainty driven by interacting pressures, including tidal flooding, salinity intrusion, shifting rainfall patterns, pest outbreaks, and rising production costs. Climate change intensifies these stressors and makes their interaction more consequential for livelihoods. The IPCC highlights that climate impacts are already widespread and that coastal systems face escalating risks associated with sea-level rise and inundation hazards that compound vulnerability over time [1]; [2]. In coastal rice systems, this increasingly translates into unstable planting calendars, disrupted drainage regimes, and heightened probability of crop loss.

These dynamics are evident in Indonesia's coastal regions, including Riau Province and Rokan Hilir Regency. Coastal risk in this setting is not reducible to "flood" or "salinity" alone; rather, it constitutes a broader risk landscape that reshapes water control, labor calendars, pest dynamics, and economic viability of farming. Rokan Hilir is also recognized in climate resilience planning as a priority location for coastal resilience actions, underscoring both exposure and policy salience [3]. Under such conditions, the continuity of farming becomes increasingly dependent on governance capacity at the community level.

In tidal coastal agriculture, the core risk is institutional as much as biophysical. Water control depends on shared canals, sluices, and embankments that connect farmers into a single interdependent system. When flooding becomes recurrent and salinity pressures intensify, farmers must coordinate water allocation, maintain infrastructures collectively, synchronize time-sensitive agricultural activities, and manage conflicts over compliance and costs. These tasks cannot be solved through household strategies alone. Evidence from environmental risk and adaptation studies shows that collective action and social networks can enhance adaptive capacity by enabling coordination, resource pooling, and shared enforcement under uncertainty [4]. Moreover, many adaptive practices become effective only when implemented in a synchronized manner across interconnected plots. Hence, the challenge of adaptation in tidal systems is fundamentally a problem of collective coordination and enforceability, not merely individual resilience.

Despite growing scholarship on climate adaptation, research still leaves a major gap in explaining how coastal farming communities manage climate risk collectively in interdependent systems. A first stream emphasizes household level adaptation through technology adoption, shifts in farm practices, and coping strategies. While this literature explains heterogeneity in adaptive behavior, it often underestimates the limits of household strategies in connected irrigation and drainage systems. Studies in Indonesia also show that vulnerability and adaptation are shaped by multiple stressors and social context rather than isolated household decisions [5]; [6]; and that adaptive capacity is embedded in socio-institutional settings that shape what is feasible in practice [7]. In tidal coastal agriculture, even strong household strategies can fail if shared water allocation arrangements, drainage regimes, and enforcement systems break down.

A second stream develops adaptation pathways, framing adaptation as evolving sequences of actions and decision points under deep uncertainty rather than one-time responses. This approach is valuable because it foregrounds learning, flexibility, and the avoidance of maladaptive lock-in [8]. Reviews show that pathways thinking has become influential in adaptation governance and climate risk decision-making [8]. Dynamic Adaptive Policy Pathways offer methods for crafting robust decisions in deeply uncertain futures [9]; and policy-oriented work links pathways approaches to implementation challenges in climate risk contexts [10]. However, much pathways research remains focused on formal planning arenas and provides limited explanation of how pathways emerge from everyday collective coordination in farming communities where governance is hybrid and partially informal.

A third stream derives from commons governance and institutional scholarship. It explains why some communities sustain cooperation in managing shared resources while others experience coordination failure. Ostrom's design principles remain foundational, emphasizing boundary clarity, monitoring, graduated sanctions, conflict resolution, recognition of the right to organize, and nested governance arrangements as key conditions for robust self-governance [11]. Research on irrigation institutions further demonstrates how these conditions support durable compliance and performance [12]; and review work confirms that the design principles function as a strong diagnostic lens for community-based resource governance outcomes [13]. Yet institutions are often treated as stable "rules in place," whereas empirical realities under chronic and multidimensional climate stress are more dynamic. Under recurring risk, institutions can weaken, shift, or strengthen, and collective practices may reorganize in composition, sequencing, roles, and enforcement.

Taken together, these bodies of literature reveal a critical gap: household-focused adaptation research often overlooks interdependence; pathways approaches can remain distant from everyday institutional mechanisms; and commons governance explains robustness but is less explicit about how collective practices evolve as pathways under recurring climate stress. What remains underexplored is how collective practices in tidal coastal agriculture are reconfigured into climate risk management pathways, and why communities exposed to broadly comparable coastal risks can exhibit divergent adaptation outcomes.

This study addresses the gap by conceptualizing climate adaptation in tidal coastal agriculture as the reconfiguration of collective practices into climate risk management pathways. We examine how communities reorganize bundles of practices, including water governance routines, collective maintenance, synchronization of key farming activities, monitoring and sanctioning, and deliberative coordination. The theoretical approach integrates adaptation pathways as evolving sequences of responses under uncertainty [8]; [9] with institutional design principles that explain collective action capacity in commons governance [11]; [12]. The central argument is that divergent adaptation outcomes among similarly exposed communities are explained less by hazard exposure alone and more by differences in institutional capacity to reorganize collective practices into workable and enforceable pathways. Accordingly, this study asks: (1) how are collective practices in tidal coastal agriculture reconfigured into climate risk management pathways; (2) what institutional conditions enable or constrain such reconfiguration;

and (3) why do communities facing comparable coastal risks produce divergent adaptation outcomes?

2 Conceptual and Analytical Framework

This study conceptualizes climate adaptation in tidal coastal agriculture as a collective risk management process unfolding under conditions of uncertainty and interdependence. In tidal systems, farming outcomes are not determined by individual household decisions alone, but by the capacity of communities to coordinate collective actions at the landscape scale. These actions include water allocation and control, maintenance of canals and embankments, synchronization of farming calendars, and compliance with collectively agreed rules. Accordingly, the framework links adaptation as an evolving sequence of responses over time with the institutional capacities that render collective action feasible, stable, and enforceable.

The analytical framework draws on two complementary theoretical anchors. First, adaptation pathways are used to conceptualize adaptation as a dynamic and sequential process rather than a one-time adjustment. Second, collective action and institutional governance theory is used to explain variation in the capacity of communities to sustain coordinated responses under shared risk. Ostrom's institutional design principles provide a diagnostic lens for assessing institutional robustness, understood here as the capacity to maintain cooperation, compliance, and conflict management over time. By integrating these perspectives, the framework treats adaptation not merely as technical change, but as the reorganization of collective practices into workable and enforceable responses to climate risk.

2.1 Adaptation Pathways and Climate Risk Management

In this study, adaptation pathways are used to capture how communities respond to climate risk through evolving sequences of collective actions. Rather than treating adaptation as a discrete intervention, the pathways perspective emphasizes that responses develop incrementally through learning, experience, and adjustment under changing environmental and socio-economic conditions [11]. Pathways thus represent trajectories of collective responses through which actors attempt to manage risk and sustain livelihoods under uncertainty.

Pathways thinking is particularly relevant under conditions of deep uncertainty, where the timing, form, and interaction of climate risks cannot be fully anticipated. Dynamic Adaptive Policy Pathways highlight how adaptation strategies may shift as conditions change, how certain decisions can constrain future options, and how sequences of responses may lead to lock-in or enhanced flexibility [12]. Subsequent work links pathways approaches to governance and implementation challenges, emphasizing that pathways are shaped not only by technical choices but also by institutional constraints and coordination capacity [13].

Analytically, this study uses adaptation pathways to examine how community-level responses to climate risk strengthen, weaken, or branch over time. The focus is not simply on which strategies are adopted, but on how sequences of collective actions are

assembled, sustained, or disrupted under recurring and multidimensional risks. This perspective allows adaptation outcomes to be analyzed as the cumulative result of sequential decisions rather than isolated responses.

2.2 Institutional Robustness and Collective Action Capacity

If adaptation pathways conceptualize adaptation as evolving sequences of responses, a critical analytical question follows: why are some communities able to sustain collective adaptation pathways over time while others experience fragmentation or collapse? To address this question, the study draws on collective action and institutional governance theory, particularly Ostrom's institutional design principles, as a diagnostic framework for explaining variation in collective capacity.

Ostrom's work demonstrates that effective governance of common-pool resources is not primarily the outcome of goodwill or cultural cohesion, but of institutional conditions that enable coordination, compliance, and conflict management over time [11]. In tidal coastal agriculture, shared resources include water infrastructures and hydrologically connected landscapes, as well as the rules governing their use, maintenance, and enforcement. Under such conditions, institutional features such as clearly defined boundaries, collective-choice arrangements, monitoring mechanisms, graduated sanctions, and accessible conflict-resolution arenas are central to sustaining cooperation under stress [11].

Research on long-enduring irrigation institutions further shows that these design principles have strong explanatory power for variation in compliance and performance [12]. This implies that the effectiveness of water-control systems depends not only on technical infrastructure, but on institutional arrangements that stabilize collective behavior over time. Importantly, Cox et al. emphasize that the design principles should not be treated as normative prescriptions, but as an analytical diagnostic tool for explaining why some community-based governance systems persist while others fail under similar pressures [13].

In this study, institutional robustness is defined as the capacity of local institutions to sustain collective action under recurring and escalating climate risks. Robustness is operationalized through the ability to establish rules perceived as legitimate, to monitor compliance in feasible ways, to apply sanctions that are fair and graduated, and to manage conflict without eroding long-term cooperation. Robustness also includes the capacity to link local governance arrangements with broader institutional structures when necessary, consistent with the principle of nested enterprises [11]. This capacity is expected to shape whether collective adaptation pathways are stabilized, weakened, or fragmented over time.

2.3 Reconfiguration of Collective Practices as an Integrative Analytical Mechanism

The integrative mechanism linking the two theoretical anchors is conceptualized as the reconfiguration of collective practices. Reconfiguration is introduced here as a working analytical concept rather than as a standalone theory. Its purpose is to bridge two analytical requirements: explaining climate adaptation as evolving pathways of collective

responses, and explaining how institutional conditions shape the formation, stabilization, or breakdown of those pathways.

In this study, collective practices are defined as coordinated actions that are effective only when implemented through compliance and synchronization at the community or landscape level. These practices include routines of water allocation and control, collective maintenance of canals and embankments, coordination of farming calendars, mobilization of collective labor, and monitoring and sanctioning arrangements. Reconfiguration refers to structural changes in these practices, including changes in the composition of actions, shifts in timing and sequencing, redistribution of roles and responsibilities, and modifications of enforcement mechanisms that stabilize or undermine compliance.

Through this lens, adaptation pathways are understood as sequences of reconfigurations in everyday collective practices rather than as outcomes of formal planning processes. At the community level, pathways emerge from repeated adjustments in how collective practices are organized, coordinated, and enforced under recurring climate stress. When reconfigurations become stabilized through institutional robustness, pathways consolidate into relatively durable routines, rules, and enforcement patterns. Conversely, when reconfiguration is partial, contested, or unsupported by adequate institutional capacity, collective responses remain episodic, fragile, or prone to fragmentation. Analytically, the framework operates as follows. Climatic and related risks generate the need for evolving collective responses over time, conceptualized as adaptation pathways [8]; [9]. Whether these pathways are sustained depends on institutional robustness, understood as the capacity to coordinate, enforce, and stabilize collective action [11]; [12]; [13]. Divergent adaptation outcomes across communities facing broadly comparable risks are thus explained by differences in institutional capacity to reorganize collective practices into stable and enforceable sequences of action.

3 Methods

This study employed a qualitative comparative case study design to examine how collective practices are reconfigured into climate risk management pathways in tidal coastal agriculture [14]. Fieldwork was conducted in Rokan Hilir Regency Riau Province Indonesia between July and December 2025. Three communities Mukti Jaya in Rimba Melintang District Teluk Piyai in Kubu District and Raja Bejamu in Sinaboi District were purposively selected based on their exposure to broadly similar tidal coastal risks and hydrologically interconnected farming systems while exhibiting variation in institutional arrangements and collective coordination capacity. This comparative logic enabled analysis of why communities facing comparable risk conditions produce divergent adaptation pathways.

Data were collected through semi structured interviews field observations and review of relevant local documents. In total 36 interviews were conducted across the three communities with 12 interviews in each site. Participants included smallholder farmers n = 22 farmer group leaders or irrigation coordinators n = 10 and other local stakehold-

ers involved in water management or collective decision-making n = 4. Sampling followed a purposive strategy aimed at capturing variation in roles directly related to collective coordination rule enforcement and maintenance of shared infrastructure. Interviews were conducted in Bahasa Indonesia typically lasting 45 to 90 minutes and were audio recorded with consent and transcribed verbatim.

Interviews focused on perceived climate and livelihood risks changes in collective practices over time coordination mechanisms labor arrangements and enforcement processes including monitoring sanctions and conflict resolution. Field observations documented shared water infrastructure collective maintenance activities and coordination practices during critical stages of the farming cycle. Relevant local documents such as farmer group records meeting notes and community agreements where available were reviewed to contextualize and corroborate interview accounts.

Data analysis followed a hybrid thematic coding strategy combining deductive and inductive approaches. Deductive coding was guided by the analytical framework particularly adaptation pathways and institutional design principles to assess institutional robustness in terms of rule legitimacy monitoring arrangements sanctioning practices conflict management and linkages to broader governance structures [11]; [12]; [13]. Inductive coding captured locally specific collective practices and their reconfiguration over time including changes in the composition of practices timing and sequencing of activities distribution of roles and responsibilities and enforcement mechanisms. Coding proceeded iteratively with categories refined through constant comparison within and across cases followed by cross case analysis to identify recurring mechanisms and divergent collective adaptation pathways [15].

Analytical rigor and trustworthiness were strengthened through triangulation across data sources and informant categories the maintenance of an audit trail documenting coding decisions and analytical memos and reflexive consideration of researcher positionality during interpretation [16]. Participation in the study was voluntary and based on informed consent and confidentiality was ensured through anonymization of individuals and sensitive community information.

4 Results

4.1 Risk Regime and Coordination Challenges

Across the three study communities, farming coordination was shaped by recurrent disruptions that farmers experienced as systemic and cyclical rather than exceptional. Risks were not perceived as single hazards but as interacting pressures that repeatedly destabilized farming routines and required collective response, a pattern consistent with documented climate related risk interactions in coastal agricultural systems [1]; [2]. Farmers consistently described climate related disturbances as conditions that could not be managed effectively at the household level because water flows, pest dynamics, and farming schedules were interconnected across plots, as is typical in tidal irrigation landscapes [7]. As a result, coordination was experienced not as an optional collective activity but as a practical necessity for sustaining farming continuity.

Two seasonal regimes generated distinct coordination challenges. During prolonged dry periods, water scarcity emerged as a central source of disruption. Farmers reported that declining water availability in canals and irrigation channels intensified competition over access, particularly between upstream and downstream users. In this context, coordination problems were framed around water turn scheduling and compliance. Without agreed allocation arrangements, upstream extraction could reduce water availability downstream and escalate conflict, a condition widely observed in shared irrigation systems [12].

In contrast, during rainy season conditions, flooding and waterlogging were described as persistent threats that disrupted planting schedules and field access. Because drainage systems and canals connect multiple plots, farmers framed excess water impacts as collective rather than individual problems. Poor drainage in one area could spill over to adjacent fields, requiring coordinated maintenance and shared response, consistent with findings from coastal flood affected farming areas [2]; [5]. Informants emphasized that decisions about delaying planting, prioritizing drainage work, and mobilizing collective labor became contentious under these conditions, especially when costs and labor contributions were unevenly distributed across households.

Beyond water related disturbances, farmers consistently highlighted biological pressures, particularly pest outbreaks, as key coordination challenges. Pest disturbances were perceived to spread across fields and to be strongly influenced by the timing of cultivation. Farmers described that asynchronous planting allowed pests to persist at landscape scale, increasing risk for all households, reinforcing the importance of synchronized farming activities as reported in studies of irrigated rice systems [7]. At the same time, farmers noted that synchronization was difficult to maintain because households differed in labor availability, financial capacity, and access to water.

Economic pressure was reported as a decisive factor shaping coordination feasibility. Farmers described how repeated losses associated with drought, flooding, pest disturbance, and operational disruption increased production costs and financial risk. In several accounts, rice farming was paused or discontinued after successive shocks because household resources were depleted, a pattern consistent with broader evidence on livelihood stress under climate variability in Indonesia [5]; [6]. Economic stress also undermined collective action by increasing the opportunity costs of participation in shared work and compliance with collective arrangements.

Farmers also reported institutional and distributional challenges that affected coordination. One recurrent issue involved contestation around access to agricultural inputs, particularly fertilizer allocation. Informants described that perceived inequality or lack of transparency in input distribution could trigger disputes and erode trust in farmer organizations, thereby complicating coordination beyond water management alone [4]. Overall, the results show that tidal coastal farming coordination was shaped by a compound risk regime involving dry season water scarcity, rainy season flooding and waterlogging, cross plot pest dynamics, and rising economic pressure. These disruptions repeatedly generated coordination challenges related to water allocation, synchronized timing, collective maintenance, and compliance, situating coordination as an ongoing and contested governance process rather than a stable condition.

4.2. Evidence of Reconfiguration of Collective Practices

Evidence from the three study communities shows that reconfiguration of collective practices emerged through repeated coordination failures, negotiation, and partial accommodation rather than through linear improvement. Across the sites, collective action was repeatedly reorganized under tidal coastal agricultural conditions characterized by hydrological interdependence, where unsynchronized practices in one plot generated spillover risks for adjacent fields, particularly in relation to water control and pest dynamics [1]; [2]; [7].

In Mukti Jaya, reconfiguration was driven by persistent failures of earlier voluntary collective labor arrangements. Prior to the adoption of organized group labor, canal cleaning, embankment maintenance, and land preparation relied on informal mutual assistance tied to farmer group membership. Although participation was framed as a moral obligation, labor contributions were uneven and difficult to coordinate. Households differed in labor availability, financial capacity, and timing of land preparation, resulting in staggered maintenance and delayed planting. Farmers repeatedly linked these delays to prolonged waterlogging and pest attacks that spread across asynchronously cultivated plots, reducing yields beyond individual farms.

These coordination failures were compounded by recurrent disputes over work order, duration of collective activities, and perceptions of unequal contribution between households with different land sizes. Because enforcement relied primarily on social pressure rather than explicit rules, non-participation was difficult to sanction without escalating conflict. Over time, repeated delays and unresolved disputes weakened trust in farmer group coordination and reduced compliance with agreed schedules.

The introduction of organized group labor, locally referred to as “pekerja borongan”, emerged as a pragmatic response to these accumulated failures rather than as a planned institutional reform. Farmer groups collectively agreed that all members planting rice within the shared farming calendar were required to use the same contracted labor group. This obligation was explicitly justified as necessary to prevent asynchronous land preparation and harvesting that could trigger pest spillover and disrupt water management across connected plots. Participation in the borongan system was therefore mandatory rather than optional for group members.

Under this arrangement, labor was compensated through a fixed percentage of output rather than daily wages. Farmers consistently reported that the prevailing rate for borongan harvesting was approximately 14 percent of total harvested yield, applied uniformly regardless of work duration or number of laborers involved. This percentage based payment was understood as a collective standard and was periodically discussed in group meetings in response to changes in production costs and labor availability. Farmers emphasized that the use of a fixed percentage facilitated rapid and simultaneous execution of harvesting across plots, which was considered critical for limiting pest persistence and production loss.

The borongan system addressed specific coordination bottlenecks by externalizing labor execution and ensuring simultaneity of key activities. However, it also generated new tensions. Disputes emerged over cost sharing, particularly between households with different land sizes and production outcomes. Farmers disagreed over whether

contributions should be calculated per household, per plot, or per hectare, and whether households experiencing crop failure should receive exemptions. Delays in payment occasionally disrupted scheduled work and reignited conflict. Over time, repeated negotiation around tariffs, contribution formulas, and payment timing contributed to partial institutionalization of the borongan arrangement, although participation remained contingent on households' ability to pay and on perceptions of fairness.

In Teluk Piyai, reconfiguration unfolded under persistent ecological constraint, particularly salinity intrusion that repeatedly undermined rice cultivation [2]; [5]. Farmers described salinity as a condition that could not be resolved through collective infrastructure or synchronized labor alone. Earlier attempts to coordinate planting schedules frequently collapsed when salinity levels rose unexpectedly, rendering agreed dates infeasible. As a result, collective practices were repeatedly reorganized rather than stabilized.

Collective meetings in Teluk Piyai shifted from coordinating joint action toward managing uncertainty and disagreement. Discussions focused on whether rice cultivation was viable in a given season and which plots could still be planted safely. Farmers reported increasing divergence in cropping strategies, including the use of salt tolerant rice varieties, short cycle crops, and alternative livelihoods. This divergence narrowed the scope for synchronized collective action and generated tension between households that continued rice farming and those that shifted away.

Labor mobilization and maintenance practices became increasingly selective. Participation varied according to perceived benefit, and enforcement of collective obligations was minimal. Non participation was often tolerated as unavoidable rather than contested, particularly when households faced repeated crop losses. Farmers described collective action as situational and provisional, activated only when immediate benefits were clear. Reconfiguration in Teluk Piyai therefore involved a contraction and fragmentation of collective practices rather than their consolidation, reflecting adaptation under ecological constraint rather than coordination success [5]; [6].

In Raja Bejamu, reconfiguration was dominated by institutional fragility and recurrent conflict. Farmers consistently described difficulties in sustaining collective practices related to water access, fertilizer distribution, and maintenance responsibilities. Earlier efforts to formalize schedules and rules frequently collapsed due to disputes over allocation and accusations of favoritism. Fertilizer distribution emerged as a recurring source of contention that undermined trust in farmer group leadership.

Enforcement practices in Raja Bejamu were shaped by the risk of open conflict. Sanctions were rarely applied because they often escalated disputes and discouraged participation. Instead, coordination was repeatedly rebuilt through negotiation following breakdowns. Monitoring relied on informal observation and personal relationships, resulting in uneven compliance. Meetings were frequently consumed by grievance airing rather than planning, delaying maintenance and disrupting farming calendars.

Although farmer groups continued to exist, collective practices in Raja Bejamu remained episodic. Maintenance activities were often postponed, partially completed, or abandoned following disagreement. Reconfiguration therefore took the form of repeated renegotiation rather than institutional stabilization. Farmers described coordination as fragile and easily disrupted, with collective action continually reassembled but

seldom routinized, a pattern consistent with stressed community based governance contexts [4]; [13].

Across the three communities, reconfiguration of collective practices did not entail the replacement of existing institutions but involved repeated adjustment of labor arrangements, decision rules, and expectations under persistent environmental, economic, and organizational pressure [1]; [7]; [11]. In Mukti Jaya, reconfiguration transformed coordination through mandatory contractual labor while generating new distributional tensions. In Teluk Piyai, it narrowed and fragmented cooperation under ecological constraint. In Raja Bejamu, it remained conflict laden and unstable, with coordination repeatedly breaking down and reforming. Together, these findings provide a non-harmonized and empirically grounded account of how collective practices were reorganized over time under similar coastal risk exposure.

4.3 Cross-case Typology of Adaptation Pathways

Cross-case analysis indicates that adaptation pathways in tidal coastal agriculture can be distinguished based on how collective practices are configured in relation to coordination enforceability and stability over time, rather than by differences in hazard exposure alone [1]; [2]. Across the cases, three recurrent configurations of collective adaptation were identified, each associated with a different village context.

The first pathway is characterized by stabilized collective coordination through enforceable obligation, in which interdependent practices are aligned by binding arrangements that limit individual discretion. In this pathway, collective action is sustained by mechanisms that prioritize temporal alignment and compliance, producing relatively predictable coordination outcomes despite ongoing negotiation. This configuration corresponds to the pathway observed in Mukti Jaya, where collective practices converged toward routinized synchronization under shared obligations rather than voluntary alignment [7]; [11].

The second pathway is characterized by selective and situational collective coordination under ecological constraint, in which collective practices persist but operate at a reduced and fragmented scale. Here, coordination is activated conditionally and remains provisional, reflecting limits imposed by environmental variability rather than institutional breakdown. Enforcement is minimal, and collective action narrows to forms that remain feasible under shifting conditions. This configuration corresponds to the pathway observed in Teluk Piyai, where adaptation proceeded through contraction and flexibility of cooperation rather than stabilization [2]; [5]; [6].

The third pathway is characterized by fragile and contested collective coordination, in which collective practices are repeatedly reassembled but rarely stabilized. In this pathway, weak enforceability and contested authority prevent the consolidation of routines, resulting in episodic coordination and recurrent breakdown. Collective action persists, but without convergence toward durable arrangements. This configuration corresponds to the pathway observed in Raja Bejamu, where adaptation remained unstable despite repeated efforts at reorganization [4]; [13].

Together, these three pathways describe distinct configurations of collective adaptation under similar coastal risk regimes. Rather than representing stages of progression

or degrees of success, the pathways capture alternative modes through which collective practices are organized, constrained, or destabilized over time in tidal coastal agriculture [1]; [2]; [11].

5 Discussion

5.1 Reconfiguration Under Constraint: Why Collective Action Changes For

The findings demonstrate that collective action in tidal coastal agriculture cannot be understood as a stable social capacity that simply persists or erodes over time. Instead, collective coordination operates as a dynamic governance response that is repeatedly reshaped by climate stress, ecological constraints, and livelihood pressures. Under conditions of hydrological interdependence and recurrent disruption, collective practices do not merely weaken or strengthen. They are actively reconfigured, meaning that communities reorganize what activities are undertaken collectively, when they are executed, how tasks are distributed, and by what means compliance is secured. This study therefore conceptualizes reconfiguration as a practical institutional mechanism through which adaptation pathways emerge, stabilize, or fragment over time. This interpretation is consistent with adaptation scholarship that emphasizes adaptation as an ongoing and iterative process shaped by repeated disturbance, uncertainty, and shifting feasibility conditions rather than as a one-off response [8]; [9]; [10].

A central implication of this perspective is that climate risk in tidal systems generates pressures that are simultaneously biophysical and institutional. Water related disturbances, including prolonged dry season scarcity and rainy season inundation, function not only as environmental shocks but also as governance stressors. They intensify interdependence in water control, canal maintenance, and planting calendars, thereby raising the coordination burden faced by farming communities. Similarly, pest outbreaks are not experienced as isolated farm level events but as landscape scale disturbances that become more severe when farming schedules are misaligned. Under such conditions, collective action becomes less a matter of symbolic solidarity and more a problem of organizing enforceable routines capable of reducing cascading risks across connected plots. Research on collective action and climate adaptation supports this view, showing that farmer groups and local organizations often function as institutional vehicles for managing shared risk, reducing transaction costs, and coordinating responses under climate variability [4]; [7].

However, the results also indicate that heightened coordination needs do not automatically translate into stable cooperation. The capacity to sustain collective action is repeatedly constrained by feasibility, understood as the practical ability of households and organizations to comply with shared routines under livelihood pressure. Many collective arrangements become fragile not because actors oppose cooperation in principle, but because compliance imposes uneven and sometimes prohibitive costs. Opportunity costs increase as households diversify livelihoods, manage competing income demands, and absorb financial losses from repeated crop failure. Adaptation research has consistently shown that institutional responses to climate risk are not neutral. They

can redistribute vulnerability and generate new burdens depending on who is able comply, who bears costs, and who benefits [5]; [6]. Consequently, collective action capacity cannot be separated from the distribution of resources and the feasibility of participation. Coordination thus emerges as a practical governance problem centered on whether shared schedules and obligations can realistically be implemented under unequal constraints.

This feasibility centered interpretation helps explain why collective action changes form rather than simply collapsing under stress. Under chronic and compounding pressure, institutions are not merely applied or abandoned. They are continually remade through everyday practice. Governance scholarship increasingly conceptualizes institutional change as occurring through flexible recombination of formal and informal elements rather than through wholesale redesign, a process commonly described as institutional bricolage. This lens is particularly useful for understanding adaptation in tidal agriculture because it captures how communities maintain coordination not by replicating idealized models of irrigation governance, but by assembling workable arrangements that fit local constraints. In this view, reconfiguration is not an anomaly or failure, but a typical adaptive response in which collective routines are repeatedly adjusted, patched, and reorganized to remain functional under shifting conditions.

Empirical variation across the study sites illustrates this logic in different forms. In Mukti Jaya, collective action did not disappear but underwent a structural transformation in how labor coordination was organized. Traditional reciprocal labor arrangements became increasingly difficult to mobilize reliably as social relations changed and time scarcity intensified. Coordination was therefore maintained through economically organized implementation, enabling synchronized routines to remain feasible despite declining availability of unpaid labor. This reconfiguration should not be interpreted as a simple market replacement of cooperation. Rather, it represents an institutional adaptation that substitutes fragile reciprocity with a more predictable coordination mechanism, thereby stabilizing collective timing and supporting pest risk management through synchronized planting. The institutional substance of collective action persists, but its operational architecture shifts. This distinction is critical for interpreting institutional robustness. What endures is not a specific cultural form of cooperation, but the capacity to sustain coordinated outcomes under constraint. Comparable dynamics have also been observed in other Indonesian community based climate initiatives, where locally embedded leadership and social capital enabled collective coordination to stabilize before formal recognition and support by the state [17].

By contrast, Teluk Piyai illustrates how ecological constraint regimes can push reconfiguration toward adaptive narrowing and coping portfolios rather than toward routinized and enforceable synchronization. Persistent dry season salinity intrusion reduces the feasible scope of rice cultivation and confines coordination to a narrow rainy season window. Under such conditions, reconfiguration does not primarily involve strengthening rules or enforcement, but reorganizing farming and livelihoods around feasibility limits. Coordination becomes seasonal and conditional, while households expand coping strategies through commodity substitution and incremental trial and error adjustments to infrastructure. This pattern aligns with broader empirical evidence from salinity affected coastal rice systems, where salinity intrusion increasingly con-

strains production choices and shifts adaptation toward changes in crops, timing, and technology packages rather than intensification of existing routines [5].

Raja Bejamu demonstrates a third configuration in which reconfiguration occurs under contested scarcity and weak institutional stabilization. In this context, scarcity intensifies distributive tensions, undermines perceptions of fairness, and weakens compliance. When water access becomes contested and monitoring capacity is limited, collective routines are prone to breakdown into episodic and reactive coordination. Institutional analyses of adaptation similarly show that stress conditions can amplify conflict and erode enforcement capacity, particularly when rule systems lack credible monitoring and dispute resolution mechanisms [11]; [12]; [13]. The outcome is not the disappearance of collective practices, but persistent difficulty in stabilizing them into predictable and enforceable routines.

Taken together, these findings advance a core argument for climate adaptation scholarship. Adaptation in interdependent agrarian systems depends not only on whether collective action exists, but on whether collective action can be reorganized into forms that remain feasible under constraint. Reconfiguration provides a mechanism-based explanation for why communities exposed to comparable climate stressors produce divergent adaptation pathways. This perspective shifts analytical attention away from viewing collective action as a fixed cultural capacity and toward understanding it as a governance arrangement that is continuously redesigned under ecological limits, economic pressure, and recurring disruption. Such a shift is essential for linking adaptation pathways thinking to institutional realities at community scale, where pathways emerge through sequences of reconfigurations rather than from static capacity alone [7]; [8]; [9]; [10].

5.2 Mechanisms of Divergence: From Similar Stress Exposure to Different Pathway Trajectories

A central contribution of this study lies in explaining why broadly comparable climate stress exposure across the three tidal coastal communities resulted in markedly different adaptation pathway trajectories. Mukti Jaya, Teluk Piyai, and Raja Bejamu were all exposed to recurring dry season water scarcity, rainy season flooding and waterlogging, cross plot pest dynamics, and rising livelihood costs. Despite these shared stressors, the communities diverged sharply in the stability of collective routines, the feasibility of synchronized action, and the continuity of rice farming. This pattern reinforces a key insight from adaptation pathways scholarship that adaptation pathways are not direct functions of hazard exposure alone, but institutional trajectories shaped by feasibility conditions, governance capacity, and ecological limits under uncertainty [8]; [9]; [10]. The analysis identifies three interacting mechanisms that together explain pathway divergence: a feasibility mechanism, an enforcement mechanism, and a constraint regime mechanism. These mechanisms determine whether collective adaptation can be stabilized into routinized and enforceable practices or whether coordination remains conditional, episodic, and vulnerable to breakdown. The overall structure of these interac-

tions is summarized in Figure 1, which links shared climate related stressors to reconfiguration drivers, reconfiguration trajectories, pathway patterns, and observed outcomes across the three communities.

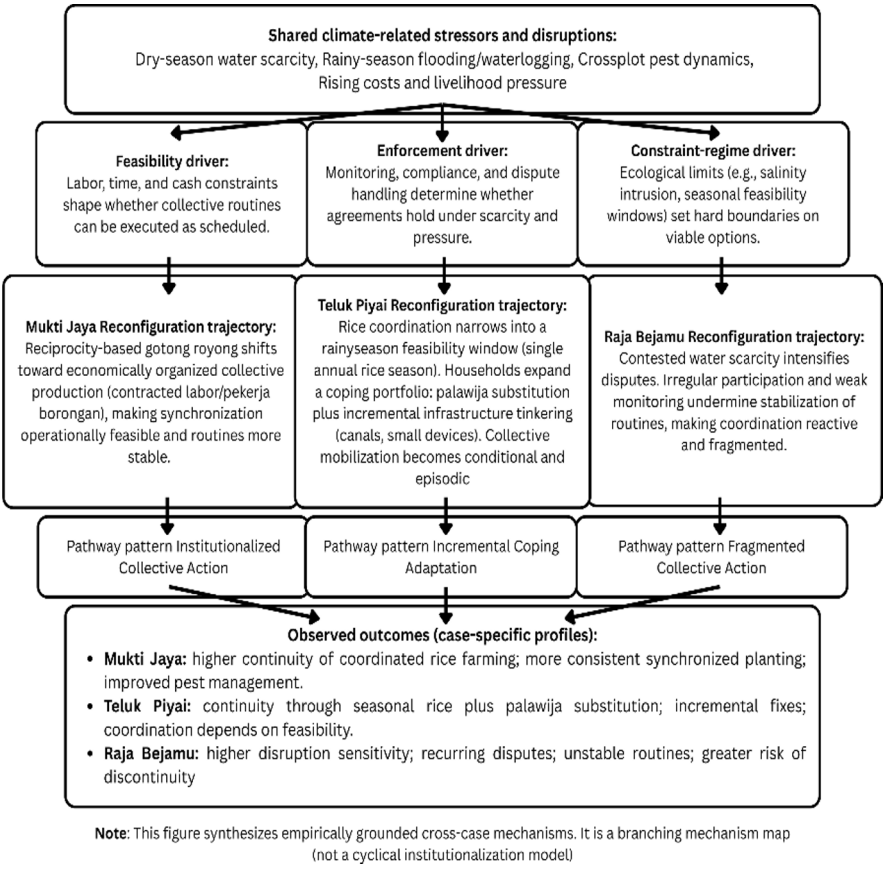

Fig. 1. Cross case mechanism map of adaptation pathway divergence.

Figure 1 synthesizes how common climate related stressors trigger three interacting reconfiguration drivers feasibility, enforcement, and constraint regime producing distinct adaptation pathway trajectories and outcome profiles across Mukti Jaya, Teluk Piyai, and Raja Bejamu.

The feasibility mechanism plays a foundational role in shaping divergence. Feasibility refers to the practical capacity of households and organizations to execute collective routines reliably under livelihood pressure. In interdependent tidal farming systems, collective action requires synchronization across actors. Synchronization becomes fragile when household labor availability, time constraints, and liquidity differ substantially. When coordination is costly in labor and opportunity terms, collective action depends on whether communities can reduce variance in implementation and prevent staggered timing. Where feasibility is enhanced, synchronized routines become implementable, enabling landscape scale pest management and reducing cascading risks

across connected plots. Where feasibility remains low, coordination tends to fragment regardless of collective intent. This interpretation aligns with institutional perspectives emphasizing that collective action success depends not only on shared preferences or norms, but on the ability to manage transaction costs, coordinate timing, and sustain cooperative investments under stress [11]; [13].

The enforcement mechanism further differentiates adaptation trajectories by shaping how agreements hold under scarcity. Enforcement refers to the capacity to monitor compliance, handle disputes, and limit defection when economic pressure increases the costs of cooperation. Under climate stress, collective arrangements face repeated governance stress tests as access becomes contested and compliance capacity uneven. Commons governance research has consistently shown that monitoring and credible enforcement are critical for sustaining cooperation under scarcity, particularly in systems where actions generate spillovers across interconnected resource units [11]; [12]; [13]. Where enforcement capacity is weak, scarcity intensifies competition and conflict, undermining routine stabilization and producing reactive and episodic coordination. Where enforcement is embedded in organizational arrangements that support monitoring and reduce timing divergence, collective routines are more likely to persist.

The constraint regime mechanism captures ecological limits that impose hard boundaries on what collective coordination can achieve. In tidal coastal agriculture, constraint regimes include salinity intrusion, tidal dynamics, and narrow seasonal feasibility windows. Under such conditions, collective action cannot always stabilize high intensity coordination regimes even when institutional capacity exists. Instead, reconfiguration often takes the form of seasonal window dependence and coping portfolios. Collective coordination is concentrated within periods when ecological conditions permit production, while households diversify strategies through crop substitution, incremental infrastructure adjustments, and livelihood diversification. This pattern is well documented in salinity affected coastal rice systems, where salinity intrusion reshapes cropping calendars and pushes adaptation toward incremental adjustment rather than intensification of existing routines [5]; [18]; [19].

Crucially, these three mechanisms interact rather than operate independently. Feasibility constraints shape enforcement capacity because households with limited resources are less able to comply, increasing monitoring burdens and conflict risks. Constraint regimes reshape feasibility by reducing expected returns to coordination, as collective effort cannot overcome ecological boundaries during unfavorable seasons. Conversely, enforcement arrangements reshape feasibility by determining whether defection and free riding destabilize collective routines. Through these interactions, comparable climate stress exposure produces sharply different institutional trajectories: consolidation of collective routines, incremental coping under seasonal constraints, and fragmented collective action under contested scarcity.

Overall, this mechanism-based explanation strengthens the pathway typology presented in the Results section by demonstrating that divergence arises from identifiable institutional processes rather than from case specific idiosyncrasies. By explicitly linking shared stressors to interacting reconfiguration drivers, the analysis clarifies how adaptation pathways emerge, stabilize, or fragment over time in interdependent agrarian systems.

5.3 Institutional Trade-offs: Effectiveness, Equity, and Legitimacy

The cross-case findings indicate that adaptation pathways in tidal coastal farming do not simply reflect different levels of collective action. Rather, they embody distinct institutional tradeoffs. Gains in effectiveness are often accompanied by costs in equity, participation, or legitimacy, while efforts to maintain broad participation may limit enforceability and coordination strength. This study therefore interprets pathway divergence through three tightly linked governance dimensions: effectiveness, defined as whether collective routines reduce risk and sustain farming continuity; equity, defined as how costs and benefits are distributed across households; and legitimacy, defined as whether actors accept and comply with collective arrangements as fair and appropriate. These dimensions are widely recognized in commons and adaptation scholarship as central to explaining why collective governance stabilizes in some contexts and fragments in others, particularly under scarcity and uncertainty [11]; [13]; [14]; [15].

From the perspective of effectiveness, the findings show that institutional performance depends less on the presence of collective norms and more on whether coordination can be translated into operationally workable routines. Mukti Jaya illustrates this dynamic clearly. The reconfigured labor system increased the feasibility of implementing synchronized routines and stabilizing timing dependent practices, thereby strengthening pest risk management and sustaining rice production continuity. In institutional terms, this pathway performs better not because it eliminates shocks, but because it reduces implementation variance across households. Such variance reduction is critical when pest dynamics and hydrological processes operate at landscape scale. This interpretation aligns with commons governance research emphasizing that institutional arrangements perform best when they are matched to local conditions, when implementation is feasible, and when monitoring is possible at the scale of interdependence [11]; [13].

Teluk Piyai demonstrates that effectiveness can take a different form when ecological boundaries constrain what coordination can achieve. Rather than institutionalizing enforceable synchronization across seasons, effectiveness is pursued through seasonal narrowing and livelihood risk spreading via coping portfolios. Collective coordination is concentrated within feasible rainy season windows, while households diversify crops and income strategies. This pattern is consistent with adaptation pathways scholarship emphasizing that when constraint regimes harden, successful adaptation often shifts from sustaining an idealized system state toward maintaining livelihoods through incremental adjustments and strategic substitutions [8]; [9]; [10]. Raja Bejamu illustrates the opposite condition. Contested scarcity repeatedly destabilizes collective routines, causing effectiveness to collapse precisely during periods of heightened risk. Under such conditions, collective action becomes reactive rather than preventive, undermining the capacity to suppress cascading disruptions.

From an equity perspective, the analysis highlights that collective adaptation is inherently distributive rather than purely coordinative. Institutions allocate burdens such as labor time and cash contributions as well as benefits such as water access, crop stability, and reduced pest exposure. Pathway divergence therefore partly reflects how

these burdens and benefits are distributed under climate stress. In Mukti Jaya, institutional consolidation improves coordination but introduces an equity tension. Synchronization becomes feasible partly because households must comply with arrangements that require payment. While this supports collective outcomes, it can disadvantage poorer households or those facing acute liquidity constraints. This pattern reflects broader evidence that adaptation arrangements can reduce vulnerability for some groups while intensifying burdens for others when participation costs are unevenly bearable [16].

Teluk Piyai presents a different equity configuration. Incremental coping pathways based on commodity substitution and household portfolio strategies can enhance flexibility, but they also shift adaptation burdens away from collective institutions and toward individual households. This shift risks widening inequality between households with assets and those with fewer viable options. Raja Bejamu illustrates how equity and conflict become structurally intertwined. When scarcity is experienced as distributively contested and access is perceived as unequal or opportunistic, cooperation becomes harder to sustain and disputes intensify. In commons settings, perceived unfairness directly undermines compliance and cooperation, particularly under scarcity conditions [11]; [13].

Legitimacy further differentiates pathway outcomes. Compliance depends not only on sanctions but on whether governance arrangements are perceived as procedurally fair, socially acceptable, and responsive to grievances. Empirical governance research shows that enforcement systems are more robust when they incorporate legitimacy building elements such as fair process and conflict resolution rather than relying solely on punitive controls [20]. In tidal farming systems, water allocation, timing synchronization, and shared maintenance inevitably generate distributive tension, making legitimacy a critical determinant of whether cooperation stabilizes or fragments. Mukti Jaya suggests that legitimacy can be supported through institutional clarity and predictable execution. Teluk Piyai suggests that legitimacy can also be maintained through institutional realism by keeping coordination conditional and feasible under salinity constraints. Raja Bejamu demonstrates how legitimacy failures can become self reinforcing, producing cycles of declining participation, weak monitoring, and opportunism.

Taken together, the findings indicate that better institutions are not simply stronger institutions. Institutional consolidation can increase effectiveness but may also raise compliance burdens and exclusion risks. Coping pathways may sustain livelihoods under constraint regimes but do not necessarily generate enforceable routines. Fragmented pathways often reflect governance breakdown under contested scarcity and weak legitimacy rather than the cultural absence of cooperation. This interpretation aligns with critical commons scholarship emphasizing that collective action should be analyzed as a dynamic political institutional process shaped by power asymmetries, participation barriers, and evolving constraints rather than as a static checklist of conditions [18]; [19]. Recognizing these trade-offs is essential for designing institutional support for climate adaptation that strengthens coordination without intensifying inequality or undermining legitimacy under stress [6].

5.4 Theoretical and Practical Implications: Reconfiguration Lens for Pathway-Based Adaptation

This study offers two interlinked contributions to adaptation pathways scholarship and to the institutional analysis of climate risk management in interdependent agrarian systems. The first contribution is theoretical. It advances reconfiguration as an analytical lens for explaining why adaptation pathways diverge across communities facing broadly comparable climate stress exposure. The second contribution is practical. It provides guidance for designing institutional and policy support that strengthens collective adaptation without generating governance burdens that are infeasible, inequitable, or legitimacy eroding.

From a theoretical standpoint, the findings reinforce the argument that adaptation pathways are best understood not as linear progressions of improving adaptation, but as sequences of institutional adjustments and reorganizations under uncertainty and constraint. This view is consistent with adaptation pathways scholarship that conceptualizes adaptation as a sequence of decisions over time under deep uncertainty, where choices may open future options or generate lock in effects [8]; [9]; [10]. However, existing pathways research often remains abstract with respect to how such sequences materialize at community scale. This study addresses that gap by demonstrating that pathways become empirically observable through reconfigurations of collective practices, including changes in practice bundles, timing structures, task allocation, and the enforceability of coordination routines.

The comparative analysis further shows that pathway divergence is produced through interacting institutional mechanisms rather than through hazard exposure alone. As demonstrated in Section 5.2, feasibility constraints, enforcement capacity, and ecological constraint regimes jointly shape whether collective institutions remain workable under recurring stress. This mechanism-based interpretation contributes to adaptation governance research by shifting analytical attention away from static capacity indicators toward dynamic institutional processes. In this sense, institutional robustness is reframed not as institutional strength in the abstract, but as the capacity to reorganize governance arrangements in ways that preserve coordination under livelihood pressure and ecological limits. This interpretation is consistent with institutional scholarship emphasizing that governance outcomes emerge from ongoing processes of institutional development and recombination rather than from fixed rule systems [11]; [13]; [21].

The reconfiguration lens also generates important conceptual insights. First, it challenges culturalized explanations of collective action that treat cooperation as a stable tradition. The findings show that cooperation persists through operational redesign rather than through the preservation of specific cultural forms. For example, in Mukti Jaya, institutional consolidation depends on economically organized labor coordination that stabilizes synchronization under conditions of labor scarcity. Second, the analysis demonstrates that reconfiguration is not inherently positive. In Teluk Piyai, reconfiguration takes the form of adaptive narrowing under ecological constraints, where coping portfolios sustain livelihoods without enabling full institutional consolidation. In Raja Bejamu, reconfiguration manifests as fragility under contested scarcity, where stress

generates fragmentation and coordination fatigue. This multidirectionality matters for adaptation pathways research because it reveals that pathways include not only incremental improvement and transformation, but also institutional destabilization and breakdown under pressure, with clear implications for maladaptation risks when governance cannot regulate access or enforce coordination [11]; [13].

From a practical perspective, the findings imply that strengthening climate adaptation in tidal coastal agriculture requires moving beyond generic prescriptions such as enhancing farmer groups or increasing participation. The most consequential leverage points are institutional and operational. Three implications follow.

First, policy interventions should prioritize coordination feasibility. Collective institutions require operational tools that reduce variance in implementation across households. This includes support for workable labor mobilization arrangements, shared scheduling mechanisms, and coordination infrastructure that enables synchronized action within narrow ecological windows.

Second, adaptation support should strengthen enforcement feasibility through legitimate monitoring and dispute handling. Under scarcity, coordination failure often arises not from lack of awareness but from contested access and unequal capacity to comply. Improving transparency in allocation, strengthening local conflict mediation, and supporting accessible dispute resolution mechanisms are therefore as important as investments in physical infrastructure.

Third, adaptation policies must explicitly recognize ecological constraint regimes. In salinity affected coastal systems, policy objectives should not be framed narrowly around increasing cropping intensity, but around enabling viable livelihood resilience within seasonal feasibility windows. This includes supporting diversified production portfolios and incremental adjustment pathways rather than imposing uniform end states that are ecologically unattainable [18]; [19].

Finally, the study has implications for operationalizing adaptation pathways in local planning. Rather than treating pathways as abstract planning diagrams, this study suggests grounding them in practice bundles and governance feasibility indicators. Monitoring systems should therefore track not only hazard frequency, but also institutional signals such as the stability of scheduling routines, compliance dynamics, conflict incidence, and the viability of synchronization mechanisms. Such indicators can help decision makers detect early shifts from consolidation to coping or from coping to fragmentation, enabling timely intervention. In sum, the reconfiguration lens provides a mechanism based framework for linking adaptation pathways planning to real world institutional dynamics in climate exposed agrarian systems.

6 Conclusion

This study examined how collective practices are reconfigured into climate risk management pathways in tidal coastal agriculture. Drawing on comparative qualitative evidence from three farming communities in Rokan Hilir Regency, Indonesia, Mukti Jaya, Teluk Piyai, and Raja Bejamu, the analysis demonstrates that climate adaptation in interdependent agrarian systems is not determined simply by the presence or absence of

collective action, but by how collective action is reorganized under ecological and livelihood constraints.

The findings show that farmers experience climate related disruptions as systemic and cyclical, shaped by dual seasonal pressures of dry season water scarcity and rainy season excess water, compounded by cross plot pest dynamics and rising production costs. These conditions generate persistent demand for collective coordination. However, collective coordination does not remain stable over time. Instead, it evolves through the reconfiguration of practice bundles, reflected in changes in practice composition, timing and sequencing, role distribution, and compliance arrangements.

Cross case comparison identified three distinct adaptation pathway patterns. Mukti Jaya followed an institutionalized collective action pathway, characterized by institutional consolidation that enhanced the feasibility and enforceability of synchronized farming routines through economically organized collective labor. Teluk Piyai followed an incremental coping adaptation pathway, shaped by ecological constraints such as salinity intrusion that narrowed rice cultivation into a rainy season feasibility window and encouraged coping portfolios including palawija (non-rice crops such as maize, cassava, and legumes) substitution and incremental infrastructure adjustment. Raja Bejamu followed a fragmented collective action pathway, where contested scarcity, weak monitoring, and recurrent disputes undermined routine stabilization and produced episodic and reactive coordination.

These findings contribute to adaptation pathways scholarship by providing a mechanism based explanation of divergence. Communities facing comparable climate stress exposure can follow different adaptation trajectories because outcomes are shaped by interacting drivers of coordination feasibility, enforcement feasibility, and ecological constraint regimes. The study advances a reconfiguration lens for pathway based adaptation, demonstrating that adaptation pathways are empirically produced through sequences of institutional redesign in everyday practice rather than through static notions of adaptive capacity alone.

From a practical perspective, the results indicate that strengthening climate adaptation in tidal coastal farming requires policy approaches that target institutional and operational leverage points. Key priorities include improving coordination feasibility through implementable scheduling and labor arrangements, strengthening legitimate enforcement and dispute resolution under scarcity, and aligning adaptation support with ecological constraint regimes rather than assuming uniform intensification goals. Recognizing institutional trade-offs among effectiveness, equity, and legitimacy is essential to avoid interventions that improve coordination while exacerbating exclusion or conflict.

This study has limitations. The qualitative design prioritizes mechanism identification and cross case explanation rather than statistical generalization. Future research could extend the reconfiguration lens through longitudinal analysis of pathway turning points, mixed method measurement of coordination stability and conflict dynamics, and comparative studies across a wider range of tidal and deltaic systems. Such work would deepen understanding of how institutional reconfiguration shapes climate adaptation trajectories under escalating uncertainty.

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