

Institutionalizing Local Wisdom: Adaptive Governance of Coastal Farmers in Responding to Climate Change in Rokan Hilir, Indonesia

Wahyudi Rambe

Universitas Abdurrab, Pekanbaru, Indonesia
wahyudi.rambe@univrab.ac.id

Kinanti Indah Safitri

Universitas Abdurrab, Pekanbaru, Indonesia
kinanti.indahsafitri@univrab.ac.id

Rofiandika Romadona Harahap

Universitas Sumatera Utara, Medan, Indonesia
andikarofi729@gmail.com

Tran Thien Nhan

Yersin University of Dalat, Viet Nam
nhantrank7@gmail.com

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Abstract:

This study analyzes how local wisdom becomes institutionalized within farmer organizations to strengthen adaptive capacity to climate change in tidal coastal agricultural systems in Rokan Hilir Regency, Indonesia. Drawing on the theoretical perspectives of adaptive governance and social–ecological resilience, the study examines how locally embedded ecological knowledge becomes translated into collectively binding rules that communities can enforce and continuously adjust in agricultural management that depends on hydrological dynamics. The research applies a qualitative approach with a multi-site case study design across five tidal coastal villages. The researcher collected data through in-depth interviews with 22 key informants, field observations, and document analysis to reconstruct cross-village institutional processes. The findings show that adaptation unfolds through recurring institutional stages, including ecological sensing and shared interpretation of tidal and salinity signals, rule formulation through collective negotiation, consolidation of collective obligations, rule enforcement through socially legitimate mechanisms, and adaptive evaluation that enables continuous adjustment. The study conceptualizes this process as the Institutionalizing Local Wisdom for Adaptive Management model, which explains how environmental knowledge transforms into coordinated and adaptive collective action. Comparative findings also reveal variations in the level of institutional consolidation across villages in organizing agricultural adaptation practices. The study confirms that strengthening local institutions plays a crucial role in enhancing the adaptive capacity of smallholder farming communities in coastal regions that face high vulnerability to climate change.

Keywords: Local Wisdom, Climate Change Adaptation, Adaptive Governance, Farmer Institutions, Tidal Coastal Agriculture, Social–Ecological Resilience.

Abstrak:

*Penelitian ini menganalisis bagaimana kearifan lokal dilembagakan dalam organisasi petani untuk memperkuat kapasitas adaptasi terhadap perubahan iklim pada sistem pertanian pesisir pasang surut di Kabupaten Rokan Hilir, Indonesia. Berangkat dari perspektif teori tata kelola adaptif dan resiliensi sosial-ekologis, studi ini menelaah bagaimana pengetahuan ekologis lokal diterjemahkan menjadi aturan kolektif yang dapat ditegakkan dan disesuaikan secara berkelanjutan dalam pengelolaan pertanian yang bergantung pada dinamika hidrologis. Penelitian menggunakan pendekatan kualitatif dengan desain studi kasus multisitus di lima desa pesisir pasang surut. Data dikumpulkan melalui wawancara mendalam dengan dua puluh dua informan kunci, observasi lapangan, dan analisis dokumen untuk merekonstruksi proses institusional lintas desa. Hasil penelitian menunjukkan bahwa adaptasi berlangsung melalui tahapan institusional yang berulang, meliputi penginderaan ekologis dan interpretasi bersama terhadap sinyal pasang surut dan salinitas, perumusan aturan melalui negosiasi kolektif, konsolidasi kewajiban bersama, penegakan aturan melalui mekanisme sosial yang memiliki legitimasi, serta evaluasi adaptif yang memungkinkan penyesuaian berkelanjutan. Proses ini kemudian dikonseptualisasikan sebagai model *Institutionalizing Local Wisdom for Adaptive Management*, yang menjelaskan transformasi pengetahuan lingkungan menjadi tindakan kolektif yang terkoordinasi dan adaptif. Temuan komparatif juga menunjukkan variasi tingkat konsolidasi kelembagaan antar desa dalam mengorganisasi praktik adaptasi pertanian. Studi ini menegaskan bahwa penguatan kelembagaan lokal merupakan faktor penting dalam meningkatkan kapasitas adaptif komunitas petani kecil di wilayah pesisir yang rentan terhadap perubahan iklim.*

Kata Kunci: *Kearifan Lokal, Adaptasi Perubahan Iklim, Tata Kelola Adaptif, Kelembagaan Petani, Pertanian Pesisir Pasang Surut, Resiliensi Sosial-Ekologis.*

INTRODUCTION

Climate change has intensified pressure on agricultural systems in Indonesia's coastal regions through rising temperatures, seasonal instability, seawater intrusion, and increasingly frequent tidal flooding (Obie, 2024; Pradipta, 2024; Riantini et al., 2024). These conditions directly affect the sustainability of agricultural systems in tidal swamp lands that strongly depend on hydrological dynamics. The Intergovernmental Panel on Climate Change reports that coastal regions constitute one of the most vulnerable areas to climate change impacts because of the combined effects of sea level rise, soil salinity, and uncertainty in rainfall patterns (Intergovernmental Panel on Climate Change (IPCC), 2023). This vulnerability becomes even more significant for smallholder farmers who manage tidal swamp rice fields with limited water management infrastructure and restricted technological capacity (Food and Agriculture Organization of the United Nations, 2015).

In Indonesia, swamp and tidal lands cover more than 20 million hectares and serve as one of the major sources of national food production (Eni et al., 2016). However, most of these lands exist under unstable hydrological conditions, characterized by fluctuating salinity intrusion and a high dependence on collective canal and water gate management (FAO, 2015). These conditions place tidal-based agricultural systems within a complex structural risk environment. In Rokan Hilir Regency, Riau Province, farmers face shifting planting patterns, unstable harvest outcomes, and increasing livelihood uncertainty as climate disturbances affect long-established farming practices (Portal Riau, 2014). Farmers increasingly struggle to predict planting windows, while canal sedimentation has intensified over the past decade and has limited farmers' ability to regulate water individually.

In the global literature, coastal and tidal swamp agricultural systems represent one of the most climate-vulnerable agrarian landscapes. Exposure to sea level rise, salinity intrusion, and hydrological instability makes agricultural production systems in these regions highly sensitive to environmental change (Food and Agriculture Organization of the United Nations, 2014; Intergovernmental Panel on Climate Change (IPCC), 2023). In the Indonesian context, this vulnerability becomes more severe because rural communities depend heavily on rice production and individual farmers possess limited capacity to control water regimes independently (Darma et al., 2025; Hatta et al., 2023; Rachman et al., 2022). Therefore, climate change adaptation cannot be understood merely as technical adjustment at the cultivation level. Adaptation must be understood as a social and institutional process that involves collective coordination, shared learning, and organized community action to sustain livelihoods. This perspective aligns with scholarship that conceptualizes adaptation as an iterative process mediated by institutions, social learning, and collective decision-making (Adger, 2003; Eriksen et al., 2015; Nelson et al., 2007; Smit & Wandel, 2006).

In the development of academic literature, three major streams of research have examined climate change adaptation in the agricultural sector. First, many studies emphasize technical and agronomic aspects, such as crop substitution, irrigation efficiency, and the development of climate-resilient varieties, but they pay limited attention to

institutional coordination mechanisms that regulate collective adaptation practices (Sekaranom et al., 2021; Stringer et al., 2020). Second, research on local institutions in common resource management highlights rule design, monitoring mechanisms, and sanction systems in managing shared resources. However, these studies often treat environmental signals as external factors rather than as elements interpreted through social processes in governance systems (Agrawal et al., 2010; Agrawal & Perrin, 2001; Ostrom, 1990; Pahl-Wostl, 2009). Third, studies on local ecological knowledge emphasize the importance of traditional knowledge in strengthening social–ecological resilience. Nevertheless, many of these studies position such knowledge merely as a cultural asset and do not explain how communities translate this knowledge into collectively binding organizational rules (Berkes, 2012; Gómez-Baggethun et al., 2012; Mercer et al., 2010).

Although these three approaches provide important contributions, a significant analytical gap remains. Many studies do not sufficiently explain how local ecological knowledge becomes translated into collective rules, how social authority legitimizes interpretations of environmental signals, and how negotiated collective obligations generate adaptive capacity under hydrological uncertainty. Most studies stop at documenting local knowledge or describing community institutions without tracing the institutionalization process that connects environmental interpretation, rule formation, and coordinated collective action (Ensor & Harvey, 2015). Consequently, scholars still poorly understand the mechanisms through which local wisdom develops into adaptive governance systems, particularly in tidal swamp agricultural contexts that depend heavily on hydrological coordination.

This limitation becomes particularly critical in agricultural systems characterized by structural interdependence among resource users. In tidal swamp systems, upstream and downstream farmers share canal networks, water gates, and interconnected drainage infrastructure (Nugroho et al., 2025; Supangat et al., 2023). Individual decisions regarding planting time or water gate operation can produce external effects for other farmers, which transforms adaptation practices into a collective action problem. Literature on adaptive governance emphasizes coordination and social learning, but it still provides limited empirical explanation of how collective ecological sensing precedes rule formation in such systems (Djalante et al., 2011; Lebel et al., 2006).

Rokan Hilir Regency provides an important empirical context to understand these dynamics. The region contains tidal rice cultivation systems, sediment-prone canals, seasonal salinity intrusion, and hydrological asymmetry between upstream and downstream areas (Muntazar, 2022; Ritonga et al., 2019). Water management in this system depends on collective coordination through shared water gate operation, synchronized planting schedules, and canal dredging activities that require negotiated compliance rather than purely individual decisions. Therefore, climate change adaptation in this context cannot be reduced to household-level farming decisions. Instead, adaptation must be understood as an institutional process embedded in everyday community governance.

Based on this context, this study aims to analyze how farmer institutions in the coastal farming communities of Rokan Hilir adapt, transform, and institutionalize local wisdom as part of strategies to build resilience to climate change. Empirically, the study examines three main dimensions: the forms of local wisdom embedded in community practices, the institutional processes that translate these values into rules and collective obligations, and the adaptive practices that emerge from these institutional arrangements.

This article argues that local wisdom can contribute effectively to climate change adaptation only when communities institutionalize it through sequential and iterative institutional processes. These processes include ecological sensing, shared interpretation of environmental signals, rule formulation through negotiation, the formation of collective obligations, and adaptive evaluation that enables continuous adjustment. In this framework, institutionalization does not merely represent the formalization of rules. Instead, institutionalization represents a social transformation process through which ecological knowledge becomes binding governance arrangements.

To explain this dynamic, this study develops the Institutionalizing Local Wisdom for Adaptive Management (ILWAM) model, which conceptualizes institutionalization as a process that connects ecological signals, social interpretation, deliberative negotiation, the formation of collective obligations, and continuous institutional learning. This model extends rule-centered institutional theory by positioning ecological sensing and collective interpretation as foundational stages that precede formal rule formation. In this way, the model complements theoretical frameworks of common resource governance and adaptive governance.

By shifting analytical attention from the question of whether local wisdom matters to the question of how communities operationalize local wisdom through institutional processes, this study contributes to the literature on climate change adaptation, institutional governance, and social–ecological resilience. Empirically, the study offers

a process-based explanation of how smallholder farming communities produce adaptive capacity in climate-vulnerable coastal agricultural systems through everyday institutional practices.

METHOD

This study analyzes the institutionalization process of local wisdom in climate change adaptation practices within coastal farming communities in Rokan Hilir Regency, Indonesia. The unit of analysis in this research is farmer organizations as institutional arenas where communities interpret ecological knowledge, negotiate meanings, and translate these interpretations into collectively binding rules and coordinated adaptive practices. The study does not position farmers as isolated individual decision-makers. Instead, it treats farmers as actors embedded within organizational structures and social relations that collectively shape agricultural governance.

This study employs a qualitative research design because it aims to reconstruct contextual and institutional social processes, including ecological interpretation, rule negotiation, authority formation, and the development of collective obligations within farming communities. A qualitative approach enables the researcher to understand institutional dynamics rooted in social practices, power relations, and cultural norms that evolve within community life. Scholars widely recognize this method as appropriate for analyzing community-based institutional dynamics and local governance practices in specific social contexts (Creswell, 2014; Moleong, 2019). In the tradition of social research in Indonesia, researchers frequently use qualitative approaches to understand local governance processes and institutional transformations embedded in sociocultural contexts (Bungin, 2007).

The study adopts an exploratory and process oriented case study design that examines multiple research sites. The research does not test a predetermined institutional framework. Instead, it inductively traces how local wisdom becomes translated into organizational arrangements through repeated interactions among actors within the community. The analytical structure of this study is organized around three main domains that correspond to the research objectives: the forms of local wisdom embedded in community practices, the institutional dynamics within farmer organizations, and the collective adaptive practices that emerge from these institutional arrangements. These analytical domains function as a framework for organizing data but do not predetermine causal sequences. The researcher inductively derives institutional stages from recurring empirical patterns observed across different village cases. After comparative analysis across villages reveals a consistent sequence of processes, including ecological sensing, shared interpretation, collective deliberation, the formation of collective obligations, and adaptive evaluation, the researcher formulates the Institutionalizing Local Wisdom for Adaptive Management (ILWAM) model as a process based conceptual abstraction grounded in empirical field evidence.

The researcher conducted fieldwork between May and December 2025 in five coastal villages: Bagan Punak Village, Rokan Baru Village, Teluk Piyai Village, Raja Bejambu Village, and Mukti Jaya Village. The researcher selected these research sites purposively based on three primary criteria: exposure to tidal flooding and salinity intrusion, dependence on shared canal networks as water management infrastructure, and the presence of active farmer organizations. These five villages also represent variations in hydrological positions between upstream and downstream areas, differences in local leadership structures, community deliberative culture, and levels of institutional maturity. This variation enables the researcher to conduct a comparative analysis of institutional dynamics that emerge under relatively similar ecological pressures.

The researcher collected data through in-depth interviews, non-participant field observations, and document analysis. The researcher conducted in-depth interviews with 22 purposively selected informants, including farmer group leaders, administrators of farmer associations, senior farmers, customary or religious leaders, and active farmer group members, including women participants. Each interview lasted between 60 and 120 minutes, and the researcher recorded all conversations with the informants' consent. The researcher conducted field observations to directly observe farmer group deliberation meetings, canal maintenance activities, synchronized planting coordination, and farmers' collective responses to tidal fluctuations. The researcher observed at least two collective activities in each research village. In addition, the researcher conducted document analysis that included farmer group statutes, meeting minutes, planting calendars, water-sharing agreements, and records of group sanctions.

The study analyzes the data using the interactive data analysis model developed by Miles and Huberman (2014). This model conceptualizes data analysis as a process that occurs simultaneously with data collection. The researcher conducts the analysis through three main stages: data condensation, data display, and conclusion drawing. During the data condensation stage, the researcher identifies and codes information related to ecological signals, deliberative practices, rule formation, mechanisms of collective obligation, rule enforcement, institutional conflicts, leadership legitimacy, and adaptive adjustments. In the next stage, the researcher performs axial coding to group these categories into broader institutional mechanisms such as boundary arrangements, resource

allocation rules, monitoring practices, and sanction procedures, which conceptually refer to institutional analysis literature in common resource management (Ostrom, 1990). The researcher then conducts selective coding to reconstruct the sequence of institutional processes that repeatedly emerge across village cases. The researcher reached thematic saturation after the fourteenth interview when no new institutional mechanisms appeared, and subsequent interviews only confirmed patterns already identified.

The researcher strengthened the credibility of the findings through methodological triangulation and data source triangulation. The researcher applied methodological triangulation by comparing interview data, field observations, and institutional documents. The researcher also applied source triangulation by involving informants from different social positions, including farmer group leaders, senior farmers, ordinary members, and women participants. The researcher conducted individual interviews outside formal group meetings to reduce elite dominance and social desirability bias. The researcher also asked probing questions regarding conflicts, tensions between upstream and downstream areas, rule violations, and non-compliance practices to obtain a more critical understanding of institutional dynamics. The researcher retained divergent narratives among informants to capture institutional variation and power relations within the community. In addition, the researcher maintained reflexive field notes throughout the research process to monitor researcher positionality and potential interpretive influence during data analysis. The study also applied ethical research procedures, including informed consent, confidentiality protection for informants' identities, and anonymization of sensitive information related to water management conflicts.

RESULTS AND DISCUSSION

Forms of Local Wisdom in Tidal Agricultural Management

Farming communities in the coastal region of Rokan Hilir Regency develop various forms of local wisdom that function as collective guidelines for managing tidal agricultural systems. This local wisdom does not initially appear as formal written rules. Instead, it emerges as ecological knowledge that communities transmit through collective experience, social interaction, and everyday practices in managing water, soil, and planting time. In the context of tidal agriculture, which strongly depends on hydrological dynamics and salinity intrusion, local wisdom becomes an important mechanism that allows farmers to interpret environmental changes and adjust their production strategies. Literature on local ecological knowledge also emphasizes that agrarian communities often develop environmental interpretation systems based on long-term experience that allow them to identify ecological changes more sensitively than purely technocratic approaches (Berkes, 2012; Gómez-Baggethun et al., 2012).

One of the most prominent forms of local wisdom involves farmers' ability to read ecological signals related to tidal dynamics and saltwater intrusion. Farmers collectively observe environmental indicators such as changes in canal water color, the smell of salinity, the direction of tidal flow, and the turbidity level of the water to determine whether the land conditions are safe for planting. Farmers do not obtain this knowledge through formal scientific measurement. Instead, they develop it through years of interaction with tidal environments. A farmer group leader in Teluk Piyai explained that farmers often discuss changes in water conditions before making decisions about planting time.

"If the water color becomes darker and the smell changes, we usually know that saltwater has started to enter. But we do not immediately decide individually. We usually compare our observations with other farmers first."
(AS, Farmer Group Leader, Teluk Piyai, Interview, July 16, 2025).

This statement shows that local ecological knowledge does not function as individual knowledge. Farmers develop this knowledge through processes of information exchange and social validation among community members. This process allows farmers to reduce ecological uncertainty that arises from differences in water conditions across different segments of the canal system. In tidal agricultural systems, water conditions in upstream areas often differ from conditions in downstream fields. As a result, planting decisions based solely on individual observation may increase the risk of crop failure.

In addition to the ability to interpret ecological conditions, farming communities also develop planting calendars based on collective experience as a form of local wisdom in organizing production cycles. These calendars do not always follow official schedules established by the government. Instead, farmers adjust planting schedules according to tidal patterns and rainfall conditions that they observe from season to season. Farmers often delay or accelerate planting time based on collective discussions regarding water and soil conditions. A senior farmer in

Raja Bejambu Village explained that farmers usually determine planting decisions after considering experiences from previous planting seasons.

“We usually observe how the water moves during the past few weeks. If we plant too early, saltwater can damage the crops. That is why we often wait until everyone agrees that the conditions are safe.” (IM, Farmer in Raja Bejambu, Interview, July 18, 2025).

This study shows that local planting calendars function as flexible adaptive mechanisms that respond to climate and hydrological uncertainty. Research on community-based adaptation also emphasizes that locally developed planting calendar systems often respond more effectively to environmental variation than standardized production calendars (Mercer et al., 2010; Smit & Wandel, 2006).

Another form of local wisdom appears in the practice of *gotong royong* in maintaining water infrastructure, particularly canals and water gates that serve as the main components of tidal agricultural systems. Farmers regularly conduct collective labor to remove canal sediment, repair embankments, and ensure smooth water flow before the planting season begins. These activities not only maintain physical infrastructure but also strengthen social coordination among farmers whose fields depend on interconnected hydrological systems. A farmer in Mukti Jaya explained that collective work ensures balanced water access for all fields.

“Usually before the planting season we clean the canals together. If the canal becomes blocked, water cannot flow properly and downstream fields can become flooded.” (MK, Farmer in Mukti Jaya, Interview, July 22, 2025).

This practice of *gotong royong* shows that farmers cannot manage water resources individually in tidal agricultural systems. Hydrological interdependence among farmers encourages collective labor as a strategy to reduce production failure risks. From the perspective of common resource governance, such practices reflect forms of social coordination that develop organically within agrarian communities (Ostrom, 1990).

Farmer group deliberation (*musyawarah*) also represents a form of local wisdom that functions as a mechanism for collective decision-making. Farmers regularly organize meetings to discuss environmental conditions, determine planting schedules, and agree on water management rules. Deliberation does not merely function as a forum for information exchange. It also becomes a negotiation space where farmers reconcile interests among those located in different positions within the canal system. In several cases, differences in land conditions between upstream and downstream areas create debates regarding the timing of water gate operations or planting schedules. However, through deliberation, farmers usually reach agreements that consider collective interests.

Local wisdom in tidal farming communities in Rokan Hilir therefore consists of a series of interconnected knowledge practices and collective actions. Ecological knowledge allows farmers to interpret environmental dynamics. Local planting calendars regulate production timing flexibly. The practice of *gotong royong* maintains the sustainability of water infrastructure. Deliberative meetings provide mechanisms for collective decision-making. These combined practices allow farming communities to manage environmental uncertainty collectively before more formal institutional rules emerge.

Table 1. Forms of Local Wisdom in Tidal Agricultural Management in Rokan Hilir

No	Form of Local Wisdom	Main Practice	Adaptive Function
1	Tidal ecological knowledge	Observing water color, salinity smell, flow direction, and tidal height	Identifying risks of salinity intrusion and determining land readiness
2	Experience-based planting calendar	Determining planting time through collective discussions based on previous seasonal experiences	Reducing crop failure risk caused by unstable water conditions
3	<i>Gotong royong</i> canal maintenance	Collective labor to remove canal sediment and repair embankments	Maintaining water flow and preventing flooding
4	Farmer group deliberation (<i>musyawarah</i>)	Regular discussions regarding water conditions, planting schedules, and water gate management	Aligning collective decisions among farmers

5	Synchronous planting norms	Informal agreements to plant at the same time	Reducing pest concentration and salinity risks
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Source: Field observations and researcher interviews (2025).

This study shows that local wisdom functions not only as traditional knowledge but also as a social mechanism that allows farming communities to collectively manage environmental uncertainty. In the context of tidal agriculture that depends heavily on sea water dynamics and salinity intrusion, these practices play an important role in sustaining agricultural production systems and strengthening community adaptive capacity in response to environmental change.

Institutional Dynamics of Farmer Organizations in the Institutionalization of Local Wisdom

The research shows that local wisdom in coastal farming communities in Rokan Hilir Regency does not automatically transform into binding rules. Farmers first interpret ecological signals collectively, and then they translate these interpretations through deliberative processes within farmer group organizations. This process shows that farmer organizations function as institutional arenas that connect local ecological knowledge with the formation of collective rules. Literature on common resource governance emphasizes that local knowledge can only become a social regulatory mechanism when communities possess deliberative forums that allow negotiation of interests and the formation of shared commitments (Clever, 2017; Ostrom, 1990).

Farmer group deliberation (*musyawarah*) serves as the primary mechanism that farmers use to discuss environmental conditions and determine collective actions. Farmers organize group meetings at the beginning of the planting season or when environmental conditions show significant changes, such as increasing salinity intrusion or shifts in rainfall patterns. During these meetings, farmers compare field observations, discuss production risks, and formulate decisions regarding planting time and water gate management. A farmer in Teluk Piyai Village explained that farmers never make planting decisions individually but always through group discussions.

“If water conditions change, we usually gather first. We discuss what each farmer observes in their fields. After that, we decide when the safest time is to begin planting.” (DA, Farmer in Teluk Piyai, Interview, July 25, 2025).

This statement shows that farmer organizations function as deliberative spaces that integrate various ecological observations into collective decisions. Without such forums, differences in land conditions between upstream and downstream areas may lead to unsynchronized planting decisions and increase the risk of crop failure.

During deliberative processes, local leadership plays an important role in facilitating discussions and mediating differences of interest among group members. Farmer group leaders or senior farmers often validate ecological interpretations before the group establishes collective decisions. The legitimacy of this leadership does not derive solely from formal organizational positions but also from long-term experience in managing tidal agriculture. A farmer in Raja Bejambu Village explained that farming communities often follow recommendations from senior farmers when environmental conditions become difficult to predict.

“We usually wait for the opinion of farmers who have lived here for a long time. They understand better how to read tidal water. If they say that the risk is still high, we usually delay planting.” (TI, Farmer in Raja Bejambu, Interview, July 23, 2025).

These findings show that local leadership legitimacy does not operate purely as administrative authority but also as authority based on ecological knowledge. Research on adaptive governance also demonstrates that socially recognized leadership can strengthen collective coordination in situations of environmental uncertainty (Folke et al., 2010).

Farmer group deliberation also functions as a space for social negotiation when farmers formulate planting rules. Differences in land conditions often generate conflicting interests between farmers in upstream areas and

those in downstream areas. Farmers in upstream areas usually have better water access and therefore tend to initiate planting earlier, while downstream farmers face higher risks of salinity intrusion. Negotiation processes therefore become necessary to align these interests so that the resulting decisions remain acceptable to all group members.

A farmer in Bagan Punak Village described this negotiation dynamic during farmer group meetings.

“Sometimes farmers upstream want to open the water gate earlier because their land is ready. But downstream farmers worry that saltwater will enter. We usually debate first until everyone agrees on the safest time.” (IW, Farmer in Bagan Punak, Interview, July 25, 2025).

This negotiation process shows that planting rules do not emerge automatically from ecological knowledge. Instead, social interactions shape these rules through discussions that consider the interests of multiple actors. This process allows farming communities to produce more stable decisions because every member participates in the rule-making process.

After the group reaches an agreement, the decisions that emerge from deliberation gradually develop into collective obligations for group members. Farmers typically establish informal norms regarding synchronized planting schedules and water gate management to reduce production risks. Compliance with these agreements does not depend solely on formal rules but also on the shared awareness that individual actions may affect the agricultural conditions of other farmers.

A farmer group leader in Teluk Piyai explained that synchronized planting becomes a collective obligation because it directly relates to pest control.

“If someone plants earlier, pests will usually gather there and then spread to other fields. That is why we agree to start planting at the same time.” (AS, Farmer Group Leader, Teluk Piyai, Interview, July 16, 2025).

In addition to forming collective obligations, farming communities also develop monitoring mechanisms and social sanctions to ensure compliance with group agreements. Farmers usually conduct monitoring informally through everyday observation of field activities and water gate conditions. Because agricultural fields operate within an interconnected canal system, farmers can easily observe changes in water conditions or differences in crop growth stages.

In several cases, farmer groups issue warnings to members who violate planting agreements or open water gates outside the agreed schedule. These sanctions generally take social forms, such as verbal warnings during group meetings or reduced trust in future decision-making processes. This mechanism shows that communities maintain compliance with group rules primarily through social pressure and reputation rather than through formal administrative sanctions.

Table 2. Institutional Mechanisms in the Institutionalization of Local Wisdom

No	Institutional Mechanism	Observed Practice	Function in Adaptation
1	Farmer group deliberation (<i>musyawarah</i>)	Meetings to discuss water conditions, determine planting schedules, and regulate water gate operations	Integrates ecological observations into collective decisions
2	Local leadership legitimacy	Farmer group leaders and senior farmers validate environmental interpretations	Facilitates coordination and resolves differences of interest
3	Negotiation of planting rules	Discussions between upstream and downstream farmers regarding planting time and water management	Produces agreements that consider shared interests
4	Formation of collective obligations	Informal norms regarding synchronized planting and water gate management	Reduces pest risks and salinity intrusion
5	Monitoring and social sanctions	Group warnings directed at members who violate agreements	Maintains compliance with group rules

Source: Field observations and researcher interviews (2025).

This study shows that the institutionalization of local wisdom develops through gradual social processes. Ecological knowledge becomes the basis for shared interpretation, farmer organizations provide deliberative arenas, and collective decisions evolve into obligations recognized by all group members. Through this process, farming communities transform ecological experience into institutional rules that support coordinated production within tidal agricultural systems.

Process of Institutionalizing Local Wisdom in Climate Change Adaptation

The research shows that local wisdom in coastal farming communities in Rokan Hilir Regency functions not only as ecological knowledge or social norms but also develops into institutional mechanisms that allow farming communities to organize adaptive responses to climate change. This process unfolds through a series of interconnected stages, beginning with the recognition of ecological signals and continuing through adaptive evaluation after the planting season. Based on field findings in five research villages—Bagan Punak, Rokan Baru, Teluk Piyai, Raja Bejamu, and Mukti Jaya—this study conceptualizes this process as Institutionalizing Local Wisdom for Adaptive Management (ILWAM). This model explains how local ecological knowledge gradually transforms into coordinated collective action to address environmental uncertainty.

The first stage in this process is ecological sensing, which refers to farmers' ability to interpret environmental signals related to tidal dynamics and salinity intrusion. Farmers observe indicators such as changes in water color, the smell of salinity, the direction of tidal flow, and water levels in canals to assess land conditions. Farmers conduct these observations continuously because hydrological conditions in tidal areas often change within short periods. Farmers do not rely solely on personal experience but also consider information from other farmers located in different canal segments. This practice allows farming communities to detect the risks of salinity intrusion earlier and adjust production decisions before crop damage occurs. Research on local ecological knowledge also shows that observation systems based on experiential knowledge often serve as important information sources for agrarian communities facing environmental variability (Berkes, 2012).

The second stage is shared interpretation, which occurs when farming communities discuss ecological observations within social forums such as farmer group deliberation meetings (*musyawarah*) or informal conversations around agricultural fields. During this stage, farmers compare and collectively verify individual observations so that the community can reach a shared understanding of current environmental conditions. These discussions are important because water conditions in upstream areas often differ from those in downstream areas within interconnected canal systems. Without shared interpretation, farmers may make unsynchronized decisions that increase the risk of crop failure.

A farmer in Teluk Piyai Village explained that farming communities usually discuss changes in water conditions before deciding planting schedules.

"We do not immediately plant when the water starts to look stable. We usually wait for observations from other farmers first so that everyone feels confident that the water conditions are truly safe." (AS, Farmer Group Leader, Teluk Piyai, Interview, July 16, 2025).

This statement shows that ecological interpretation does not occur individually but develops through processes of information exchange and social validation. In the context of climate change adaptation, shared interpretation mechanisms allow farming communities to reduce informational uncertainty before making production decisions.

The third stage is rule articulation, which occurs when communities translate shared interpretations into collective rules within farmer organizations. These rules usually relate to synchronized planting schedules, regulation of water gate operations, and canal maintenance schedules. Rule formulation processes do not always occur without conflict because farmers often possess different interests depending on the location of their fields within canal systems. Farmers located in upstream areas often prefer earlier water gate openings, while downstream farmers remain more concerned about saltwater intrusion.

A farmer in Bagan Punak Village described the negotiation dynamics that occur during farmer group deliberation meetings.

“Farmers upstream sometimes want to open the water gate earlier because their fields are ready. But farmers downstream worry that saltwater may enter. We usually discuss the situation until we find the safest timing for everyone.” (KS, Farmer in Bagan Punak, Interview, July 26, 2025).

This finding shows that planting rules do not automatically emerge from ecological knowledge but develop through social negotiation processes within farmer organizations. These processes allow communities to produce decisions that consider the interests of different actors while maintaining production system stability. The fourth stage is collective obligation, which occurs when agreed rules gradually develop into shared obligations for all farmer group members. Farming communities usually establish informal norms that require members to follow agreed planting schedules and water management practices. Compliance with these rules emerges because farmers understand that individual actions can influence the land conditions of other farmers within the same canal system.

The farmer group leader in Teluk Piyai explained that synchronized planting becomes a collective obligation because it directly relates to pest control.

“If someone plants earlier, pests usually gather in that field first and then spread to other fields. That is why we agree to plant at the same time.” (AS, Farmer Group Leader, Teluk Piyai, Interview, July 16, 2025).

These collective norms strengthen coordination among farmers because every member understands that production success does not depend solely on individual decisions but also on compliance with shared rules. The fifth stage is adaptive evaluation, which occurs when farming communities reassess the outcomes of previous planting seasons and adjust established rules. Farmers usually discuss experiences of production success or failure during farmer group meetings after harvest. These evaluations often result in adjustments to planting schedules, water management strategies, or patterns of collective cooperation.

A senior farmer in Raja Bejamu Village explained that farming communities often adjust planting decisions based on experiences from previous seasons.

“We once planted too early because rain arrived earlier than expected. After that many crops were damaged. Since then we agreed to wait until the water conditions become truly stable.” (IM, Farmer in Raja Bejamu, Interview, July 18, 2025).

Adaptive evaluation allows farming communities to revise institutional rules based on empirical experience. This process shows that farmer group rules remain dynamic rather than static and continue evolving according to changing environmental conditions and production experiences.

Although institutionalization stages appear in all research villages, the level of institutional consolidation differs across locations. Mukti Jaya Village shows relatively stronger coordination than other villages because farmer groups in this village develop more organized collective mechanisms, including coordinated labor arrangements to ensure synchronized planting. In other villages such as Rokan Baru or Teluk Piyai, farmer group coordination relies more strongly on social norms and the reputations of group members.

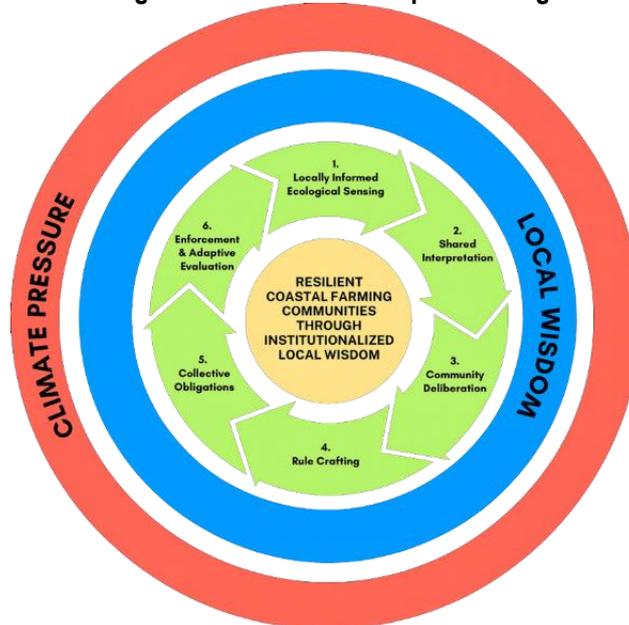
Table 3. Comparison of Institutionalization Processes of Adaptation in Research Villages

Village	Main Coordination Practice	Form of Institutional Strengthening	Adaptation Character
Bagan Punak	Intensive deliberation regarding water gate management	Agreement on planting time and water flow regulation	Negotiation-based adaptation
Rokan Baru	Information exchange among farmers in the field	Planting consensus after verification of water conditions	Social coordination-based adaptation
Teluk Piyai	Farmer group discussions regarding salinity conditions	Synchronized planting norms	Collective norm-based adaptation
Raja Bejamu	Ecological interpretation validated by senior farmers	Planting decisions based on ecological experience	Knowledge authority-based adaptation
Mukti Jaya	Coordinated planting schedules and group labor arrangements	Strengthening of farmer group organization	Institutionally consolidated adaptation

Source: Field observations and researcher interviews (2025).

Based on these findings, this study proposes the Institutionalizing Local Wisdom for Adaptive Management (ILWAM) model as a conceptual framework for understanding the institutionalization of local wisdom in climate change adaptation within tidal agricultural systems.

Figure 1. Institutionalizing Local Wisdom for Adaptive Management (ILWAM) Model



Source: Developed by the author based on Ostrom (1990); Berkes (2012); Folke et al. (2005); Pahl-Wostl (2009).

Figure 1 presents the Institutionalizing Local Wisdom for Adaptive Management (ILWAM) model as a conceptual framework that explains how local wisdom develops into adaptive institutional mechanisms within coastal agricultural systems facing climate pressures. The model shows that adaptation does not occur spontaneously or individually. Instead, institutional cycles shape adaptation by linking local ecological knowledge with social deliberation processes, collective rule formation, and repeated adaptive evaluation. The outer circle of the model represents the broader context of climate pressure, including environmental stresses such as salinity intrusion, tidal fluctuations, and seasonal uncertainty that influence coastal agricultural production systems. In climate adaptation literature, environmental pressures often trigger social learning processes and collective coordination within local communities (Folke et al., 2005; Smit & Wandel, 2006).

The second layer of the model shows local wisdom as the foundational knowledge possessed by farming communities. This local wisdom includes collective experiences in interpreting tidal dynamics, recognizing changes in water quality, understanding seasonal patterns, and managing social relationships within agricultural practices. This knowledge remains dynamic rather than static because interactions among farmers and repeated production experiences continuously reshape it. In social-ecological system studies, scholars often describe local ecological knowledge as a form of traditional ecological knowledge that enables communities to understand environmental dynamics through empirically grounded experiences transmitted socially across generations (Berkes, 2012; Gómez-Baggethun et al., 2012). Consequently, local wisdom functions as an ecological information source that allows farming communities to detect environmental changes more quickly than formal observation systems.

At the core of the model, the adaptation process appears as an institutional cycle consisting of interconnected stages. The first stage is locally informed ecological sensing, which refers to the capacity of farming communities to interpret ecological indicators related to tidal conditions and salinity levels. Farmers observe changes in water color, salinity smell, tidal flow direction, and canal water levels as the basis for assessing land readiness. Farmers do not conduct this process individually but through information exchange among farmers located in different segments of the canal system. Literature on social-ecological systems shows that shared environmental observation often becomes the initial stage in forming adaptive responses within natural resource-dependent communities (Berkes, 2012; Folke et al., 2010).

The second stage is shared interpretation, in which farmers collectively discuss ecological information within social forums such as farmer group deliberation meetings. During this stage, farmers compare and verify individual observations so that communities can reach a shared understanding of environmental conditions. This process remains important because tidal agricultural systems contain strong hydrological interdependence between upstream and downstream fields. Without collective interpretation, individually made production decisions may produce unsynchronized planting schedules and increase crop failure risks. Research on community-based adaptation also emphasizes that collective interpretation of environmental risks represents an essential component of social learning in climate adaptation processes (Ensor & Harvey, 2015; Smit & Wandel, 2006).

The next stage is community deliberation, which refers to the discussion and social negotiation processes that occur within farmer organizations to formulate collective responses to interpreted environmental conditions. During this stage, farming communities discuss various action alternatives, including planting schedules, water gate operation management, and canal maintenance arrangements. Deliberation often involves conflicting interests among farmers, particularly between upstream and downstream farmers who face different levels of salinity risk. Through discussion and negotiation, farming communities attempt to reach decisions that appear fair and safe for all group members. In adaptive governance studies, collective deliberation processes represent important mechanisms for building legitimacy in shared natural resource management decisions (Lebel et al., 2006; Pahl-Wostl, 2009).

The results of deliberation then develop into rule crafting, which refers to the formulation of collective rules that regulate agricultural practices and water management. These rules usually include agreements regarding synchronized planting schedules, water flow regulation within canal systems, and obligations to participate in agricultural infrastructure maintenance activities. These rules may take written or unwritten forms, but they possess strong social legitimacy because they emerge from farmer group deliberation processes. At this stage, local ecological knowledge begins to transform into institutional structures that regulate collective community behavior. This process aligns with common pool resource governance theory, which shows that local communities can design their own rules to manage shared resources sustainably (Ostrom, 1990).

The next stage is collective obligations, which occurs when formulated rules develop into social obligations that all community members must follow. These collective obligations emerge because farming communities recognize that production success does not depend solely on individual decisions but also on coordinated actions among farmers within interconnected agricultural systems. Compliance with shared planting rules helps reduce pest risks and maintain balanced water distribution within canal networks. In common resource governance theory, the formation of collective norms and social obligations represents an important mechanism that strengthens rule compliance in local communities (Agrawal et al., 2010; Ostrom, 1990).

The final stage in this cycle is adaptive evaluation and adjustment, which refers to evaluation processes conducted by farming communities after harvest seasons conclude. During this stage, farmers discuss experiences of production success and failure to assess whether implemented rules remain relevant under changing environmental conditions. Farmers then use these evaluation results to adjust planting schedules, water management strategies, or forms of collective cooperation for the next planting season. This evaluation process shows that adaptation within farming communities remains dynamic and continues evolving alongside ecological change. Within adaptive governance frameworks, learning and institutional adjustment processes represent key mechanisms for sustaining complex social-ecological systems (Folke et al., 2010; Pahl-Wostl, 2009).

The ILWAM model therefore illustrates that climate change adaptation in coastal agricultural communities emerges through an institutional cycle that links local ecological knowledge, social interaction, and collective rule formation. Through this cycle, farming communities transform local experience into adaptive governance systems that strengthen agricultural production resilience under climate pressures. The model also demonstrates that successful adaptation does not depend solely on agricultural technological innovation but also on the institutional capacity of communities to organize local knowledge into sustainable mechanisms of collective coordination.

DISCUSSION

This study shows that climate change adaptation in coastal farming communities in Rokan Hilir Regency develops through a structured and recurring process of institutionalizing local wisdom. The findings reveal three interconnected results. First, farming communities develop ecological signal interpretation systems that allow them to detect changes in tidal dynamics and salinity intrusion before making production decisions. Second, farmer group organizations function as deliberative arenas that connect ecological interpretation with the formulation of collective rules regarding planting schedules and water management. Third, agreements produced in these forums gradually

develop into collective obligations that communities monitor through social mechanisms and periodically evaluate based on production experience. These findings demonstrate that local wisdom does not function merely as traditional knowledge but also as an institutional mechanism that allows farming communities to organize adaptive responses to environmental uncertainty.

In the development of academic literature, scholars have identified three main research streams concerning climate change adaptation in the agricultural sector. First, most studies emphasize technical and agronomic aspects such as crop variety substitution, irrigation efficiency, and the development of climate-resilient crop varieties. This approach focuses on technological innovation in production systems but gives limited attention to institutional coordination mechanisms that regulate collective adaptation practices at the community level (Sekaranom et al., 2021; Stringer et al., 2020). Second, studies on local institutions in common resource management emphasize rule design, monitoring mechanisms, and sanction systems that regulate the behavior of resource users. However, these studies often treat environmental signals as external factors that influence actor behavior without explaining how communities first interpret ecological conditions before collective rules emerge (Agrawal et al., 2010; Ostrom, 1990; Pahl-Wostl, 2009). Third, research on local ecological knowledge emphasizes the importance of traditional knowledge in strengthening social-ecological resilience. However, most studies position such knowledge primarily as a cultural asset embedded within communities without explaining the institutional processes that transform this knowledge into collectively binding organizational rules (Berkes, 2012; Gómez-Baggethun et al., 2012; Mercer et al., 2010).

The findings of this study contribute empirically to these three streams of literature by showing that climate change adaptation in farming communities does not depend solely on technical innovation or the existence of local knowledge. Instead, adaptation depends on institutional processes that connect ecological knowledge with collective action. Farmers in Rokan Hilir do not immediately convert environmental observations into production rules. Instead, farmers first discuss these observations within social forums and then formulate collective rules through negotiation processes within farmer group organizations. This process shows that climate change adaptation represents a social phenomenon that involves shared interpretation, institutional coordination, and the formation of collective commitments.

The primary contribution of this study lies in the development of the conceptual framework Institutionalizing Local Wisdom for Adaptive Management (ILWAM), which explains the stages through which local wisdom becomes institutionalized in climate change adaptation processes. The model shows that adaptation develops through five interconnected stages: ecological sensing, shared interpretation, rule articulation, collective obligation, and adaptive evaluation. During the ecological sensing stage, farmers interpret environmental signals such as changes in water color, salinity odor, and tidal levels to assess land conditions. During the shared interpretation stage, farming communities discuss these observations within farmer group deliberation forums. During the rule articulation stage, farmer groups translate ecological interpretations into collective rules regarding planting schedules and water management. During the collective obligation stage, these rules evolve into shared obligations recognized by group members. During the adaptive evaluation stage, farming communities evaluate previous planting seasons and adjust production rules according to changing environmental conditions (Berkes & Ross, 2013; Folke et al., 2005; Ostrom, 1990; Pahl-Wostl, 2009).

The ILWAM framework expands perspectives within adaptive governance studies by showing that the formation of collective rules does not begin with institutional design but instead emerges from socially constructed ecological interpretation processes. Literature on common resource governance generally emphasizes the importance of rule design, monitoring mechanisms, and sanctions in maintaining sustainable resource management (Ostrom, 1990). This study demonstrates that these institutional rules cannot form effectively without collective understanding of the ecological conditions faced by the community. In other words, shared interpretation of environmental signals constitutes a crucial prerequisite for the emergence of institutional coordination in tidal agricultural systems.

While common pool resource governance theory provides a robust explanation of how rule configurations sustain collective resource management, it offers more limited insight into the earlier social processes through which ecological knowledge becomes collectively interpreted and translated into institutional rules. The ILWAM framework developed in this study addresses this analytical gap by tracing the institutionalization process that precedes rule formation. Rather than focusing primarily on rule design, the ILWAM model explains how ecological sensing, shared interpretation, and deliberative negotiation generate the epistemic and social conditions necessary

for the emergence of collectively binding rules. In this sense, the ILWAM model complements the Institutional Analysis and Development perspective by specifying the pre-institutional processes through which environmental knowledge becomes institutionalized within community governance systems.

The findings also reveal variation in institutional consolidation across the research villages. Mukti Jaya Village demonstrates relatively stronger coordination because farmer groups in this village develop more structured organizational mechanisms for managing collective labor and water management practices. In other villages such as Teluk Piyai and Rokan Baru, production coordination depends more heavily on social norms and the reputations of group members. This variation indicates that the institutionalization of local wisdom does not occur uniformly but depends on local organizational capacity, leadership structures, and the degree of hydrological interdependence among farmers. These findings align with previous studies showing that successful adaptive governance strongly depends on local institutional configurations and levels of social trust within communities (Berkes & Ross, 2013; Folke et al., 2005).

In addition to theoretical contributions, this study also offers practical implications for climate change adaptation policies in the agricultural sector. Adaptation programs often focus on transferring agricultural technologies or developing irrigation infrastructure without considering the social mechanisms that regulate production coordination at the community level. The findings of this study show that successful adaptation does not depend solely on technology but also on the ability of farming communities to organize local knowledge into collective rules that communities can implement consistently. Therefore, adaptation policies should not focus exclusively on introducing technical innovations but should also strengthen the organizational capacity of farmer groups as arenas for deliberation and coordination in water resource management.

This study confirms that local wisdom plays an important role in strengthening the adaptive capacity of farming communities facing climate change. However, this role can only become effective through institutionalization processes that translate local knowledge into coordinated collective action. By integrating analysis of local ecological knowledge, farmer organizational dynamics, and the formation of collective rules, this study provides a more comprehensive understanding of how agrarian communities develop institution-based adaptation strategies to respond to changing environmental conditions.

CONCLUSION

This study shows that climate change adaptation in coastal farming communities in Rokan Hilir Regency represents a complex social and institutional process that develops through the institutionalization of local wisdom in tidal agricultural management. Farming communities do not rely solely on traditional ecological knowledge to interpret environmental changes. Instead, they organize this knowledge through farmer group deliberation mechanisms, the formulation of collective rules, and the establishment of shared obligations in managing planting schedules and water governance. Climate change adaptation therefore does not occur as an individual decision at the household level but develops as a collective coordination process mediated by local organizations and social norms within the community.

The findings demonstrate that local wisdom functions as a knowledge infrastructure that allows farming communities to detect ecological changes, reduce environmental uncertainty, and coordinate production activities collectively. The process of shared interpretation of ecological signals becomes an important initial stage before institutional rules emerge. Farmer groups then function as deliberative arenas that translate these interpretations into collectively agreed rules for planting schedules and water management. These rules gradually develop into collective obligations that communities monitor through social mechanisms such as reputation, peer monitoring among farmers, and the reinforcement of cooperative norms. Farming communities then periodically evaluate these processes based on production experience in order to adjust rules to changing environmental conditions.

The primary contribution of this study lies in the development of the conceptual framework Institutionalizing Local Wisdom for Adaptive Management (ILWAM), which explains how local wisdom can develop into an adaptive governance system within coastal agricultural communities. The model demonstrates that adaptation occurs through five interconnected stages: ecological sensing, shared interpretation, rule articulation, collective obligation, and adaptive evaluation. This framework expands climate change adaptation literature by showing that adaptation effectiveness does not depend solely on technological innovation or the presence of local knowledge but also on the ability of communities to institutionalize this knowledge into collective rules that communities can implement consistently.

The study also reveals that the level of institutional consolidation in adaptation practices does not appear uniform across villages. Mukti Jaya Village demonstrates stronger institutional coordination through organized

collective labor arrangements and stronger farmer group organizations. In contrast, other villages such as Teluk Piyai, Raja Bejalu, and Rokan Baru rely more heavily on social norms and local leadership to maintain compliance with shared planting rules. This variation shows that community adaptive capacity does not depend solely on ecological conditions but also depends on local institutional structures, leadership legitimacy, and the strength of social networks within farming communities.

From a theoretical perspective, this study contributes to the development of adaptive governance and social-ecological resilience studies by emphasizing the importance of institutionalization processes that connect local ecological knowledge with collective action. The findings demonstrate that scholars should not interpret local wisdom solely as cultural tradition but should recognize it as a knowledge resource that can evolve into adaptive governance mechanisms when communities organize it through effective social and institutional processes.

Future research on climate change adaptation in coastal agricultural communities should expand its focus toward local institutional dynamics that connect ecological knowledge, farmer organizations, and production coordination. Longitudinal studies examining changes in adaptation practices within farming communities may provide deeper understanding of how collective rules evolve over time. In addition, comparative research across coastal regions in Indonesia may enrich understanding of variations in institutional adaptation across different social and ecological contexts. Such approaches remain important to ensure that climate change adaptation policies do not focus exclusively on technical solutions but also strengthen local institutional capacity as the primary foundation for resilient and sustainable agricultural development.

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The author conceptualized the study, designed the research framework, and conducted data collection and analysis. The author also developed the analytical model, interpreted the findings, and wrote the manuscript. All stages of the research and publication process were carried out by the author

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