



## Climate-Driven Agricultural Transformation in Vietnam's Coastal Red River Delta: Eco-Dynamic Adaptation and Governance Responses

Khuyen Thi Nguyen<sup>1\*</sup> , Toan Duc Nguyen<sup>2</sup> , Minh Ngoc Thi Tran<sup>1</sup> 

<sup>1</sup> Faculty of Political Economy, Academy of Journalism and Communication, Hanoi 100000, Vietnam

<sup>2</sup> Academy of Journalism and Communication, Hanoi 100000, Vietnam

Corresponding Author Email: [nguyenthikhuyen@ajc.edu.vn](mailto:nguyenthikhuyen@ajc.edu.vn)

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### ABSTRACT

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Coastal delta agriculture is increasingly exposed to climate stress, but adaptation outcomes vary across local governance contexts. This study examines climate-driven agricultural transformation in six coastal districts of Vietnam's Red River Delta (RRD) during 2010–2017, with particular attention to how district-level governance mediates adaptation. Using a mixed-methods design, the study combines longitudinal agricultural indicators with farmer surveys and interviews with local officials. The findings show a gradual shift from rice-dominated systems toward aquaculture and integrated crop–livestock models, accompanied by modest growth in agricultural output and rural income. However, adaptation remains uneven across districts. Areas with stronger extension services, technical support, infrastructure provision, and institutional responsiveness show more proactive adaptation, while districts with weaker coordination and limited support experience more constrained responses. The study contributes to climate-adaptation literature by shifting the focus from land-use change alone to governance-mediated adaptation across multiple coastal districts. The findings highlight the need for integrated land-use planning, localized infrastructure investment, stronger extension systems, and inter-district coordination to support resilient and sustainable agricultural development in climate-vulnerable delta regions.

## 1. INTRODUCTION

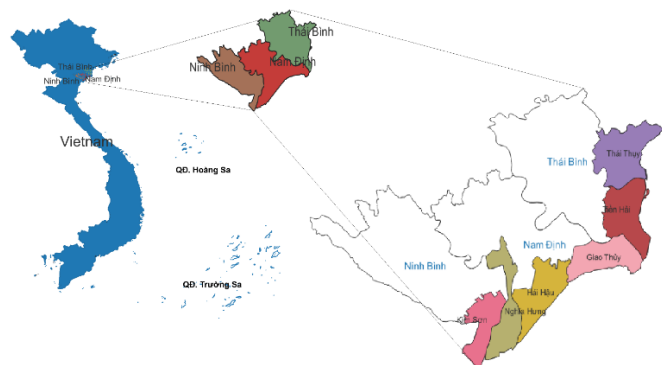
Agriculture remains a foundational sector of Vietnam's economy, underpinning national food security, rural employment, and livelihood stability. Within this context, the coastal Red River Delta (RRD)—including *Quảng Ninh, Hải Phòng, Thái Bình, Nam Định, and Ninh Bình* provinces (Figure 1)—has historically functioned as a highly productive and ecologically complex agricultural system. Shaped by fertile alluvial plains, dense river networks, and an extensive coastline, the region has supported diversified farming systems combining rice cultivation, aquaculture, and livestock production. These characteristics have positioned the coastal RRD not only as a major agricultural zone, but also as a dynamic human–environment system integral to Vietnam's long-term development trajectory.

Over recent decades, however, the functional stability of this agricultural system has been increasingly disrupted by climate change. As a low-lying deltaic landscape, the RRD is particularly exposed to sea-level rise, salinity intrusion, drought, and extreme weather events. These pressures have accelerated land degradation, reduced the availability of arable land, altered hydrological regimes, and disrupted traditional cropping calendars, thereby placing growing stress on rural livelihoods. Empirical studies by Nguyen et al. [1], Yuen et al. [2], and Vu [3] demonstrate that climate change has already

induced significant structural changes in agricultural production systems across the region, while simultaneously exposing weaknesses in existing management and adaptation practices. More recent research further indicates that environmental stressors interact with broader challenges related to sustainable livelihoods, human resource capacity, and institutional effectiveness in Vietnam's rural development process [4–8]. Recent studies in sustainable development and planning also show that environmental transformation must be understood together with governance capacity, spatial coordination, institutional design, and strategic policy response [9–11]. Collectively, this body of work underscores the need to approach climate adaptation as a systemic process that integrates environmental dynamics with social and institutional design.

Although agricultural modernization and environmental adaptation in Vietnam have been widely examined [12, 13], district-level analyses of how public management systems respond to climate change in the coastal RRD remain limited. This gap is significant because district authorities play a central role in translating national policies into practice, coordinating infrastructure investment, and engaging directly with farming communities. These functions are critical for shaping adaptive outcomes in climate-vulnerable landscapes. As noted by Dinh and Thi [4], sustainable rural livelihoods depend on governance arrangements that integrate spatial

planning, cultural values, and environmental adaptation. Similarly, Hong et al. [5] and Thanh et al. [6] emphasized that local human resource governance strongly influences innovation capacity and resilience under sustainability pressures. In a broader governance context, Nguyen et al. [10] argued that sustainable development in Vietnam increasingly requires leaner, more decentralized, and digitally enabled governance systems, while Lai and Tran [9] demonstrated the importance of integrating spatial planning with social welfare objectives. Although these studies focus on urban governance and urban welfare, their emphasis on institutional coordination, decentralized implementation, and place-based planning is relevant to climate adaptation in rural and coastal settings. Understanding how district-level institutions operate in practice is therefore essential for evaluating the effectiveness of agricultural adaptation in the RRD.



**Figure 1.** Survey locations in the coastal Red River Delta (RRD) (Vietnam)

Note: Map created by the authors using QGIS, based on district-level data from Thái Bình, Nam Định, and Ninh Bình provinces (2025).

This study responds directly to a more specific research gap in the literature. Previous studies have already shown that climate change contributes to agricultural land-use change and household-level adaptation in coastal Vietnam. In particular, Nong et al. [14] provided important evidence on climate-driven agricultural land-use change in *Tiên Hải* District, *Thái Bình* Province, using satellite remote sensing and household survey data. However, the present study differs from that work in both analytical scope and explanatory focus. Rather than examining land-use change in a single district, this article adopts a comparative district-level perspective across six coastal districts of the RRD. Its contribution is therefore not merely geographic expansion or broader narrative framing. Instead, the study explains how similar climate-related pressures produce uneven adaptation outcomes because district-level governance capacity, infrastructure provision, extension services, institutional coordination, and local implementation conditions vary across space.

The central analytical argument of the article is that climate-driven agricultural transformation in the coastal RRD is a governance-mediated adaptation process. Climate stressors such as salinity intrusion, sea-level rise, drought, and hydrological variability create pressure for agricultural restructuring, but the direction and effectiveness of this restructuring depend on local governance conditions. Districts with stronger irrigation systems, extension services, technical assistance, financial support, and coordination mechanisms are better positioned to support proactive adaptation, while districts with weaker institutional capacity are more likely to experience reactive, fragmented, or uneven responses. This

governance-mediated perspective allows the study to move beyond documenting agricultural change as an outcome and instead examine the mechanisms through which adaptation is enabled, constrained, or unevenly implemented.

Against this background, the present study examines agricultural development in the coastal RRD during the period 2010–2017, with particular attention to climate-induced transformation and local adaptive responses. The study pursues three specific objectives: (i) to analyze changes in agricultural production patterns under climate-related pressures; (ii) to compare how district-level governance conditions shape local adaptation outcomes across six coastal districts; and (iii) to identify evidence-based policy directions for strengthening sustainable, climate-resilient, and governance-supported agricultural transformation. These objectives respond to the need for a more explicit comparative analysis of how local governance systems mediate adaptation under similar climate pressures.

To achieve these objectives, the research adopts a mixed-method approach that integrates quantitative analysis of agricultural performance indicators with qualitative evidence from field surveys and interviews conducted in six coastal districts—*Thái Thụy*, *Tiên Hải*, *Giao Thủy*, *Hải Hậu*, *Nghĩa Hưng*, and *Kim Sơn* (Figure 1). The selection of these districts enables comparison across localities that share exposure to coastal climate risks but differ in infrastructure conditions, agricultural restructuring pathways, extension-service access, and governance responsiveness. The analysis is situated within national and international scholarship on agricultural governance, climate adaptation, and rural development, while maintaining a district-level empirical focus. In this respect, the study also builds on recent strategic work on agricultural transformation in Vietnam, including SWOT–TOWS analysis by Nguyen et al. [11] of environmental impacts and strategic responses in Dong Nai Province. While that study emphasizes provincial-level strategic planning, the present article contributes a district-level governance comparison in a climate-vulnerable coastal delta context.

Beyond its economic function, the coastal RRD constitutes a living agricultural heritage landscape shaped by long-standing irrigation practices, rice-based cultural traditions, and community-oriented farming systems. Consistent with Dinh and Thi [4] and Ngoc and Duc [8], this study conceptualizes agricultural landscapes not merely as production spaces, but as socio-ecological systems in which cultural continuity, ecological processes, and human management are deeply intertwined. Under conditions of intensifying climate stress, safeguarding this agrarian heritage becomes inseparable from sustaining livelihoods, maintaining collective identity, and preserving ecological integrity. The integration of heritage conservation with climate adaptation therefore emerges as a central challenge for sustainable landscape management in the region.

The article makes three contributions. First, it clarifies that agricultural adaptation in the coastal RRD is not simply a direct response to climate stress, but a governance-mediated process shaped by district-level institutional capacity. Second, it provides comparative evidence across six coastal districts, showing how adaptation outcomes differ according to infrastructure, extension services, technical support, and policy implementation conditions. Third, it links agricultural transformation to sustainable development planning by demonstrating that climate adaptation requires integrated land-use planning, inter-district coordination, and locally

responsive governance rather than isolated technical interventions.

The remainder of the article is organized as follows. The Literature Review examines existing research on agricultural development pathways, climate adaptation, land-use transformation, and governance-mediated resilience. The Methodology section presents the mixed-method research design, study sites, data sources, and comparative analytical framework. The Results and Discussion section analyzes empirical findings related to agricultural transformation, climate impacts, district-level governance capacity, and policy implications. The Conclusion summarizes the main findings, theoretical contribution, practical implications, limitations, and directions for future research.

## 2. LITERATURE REVIEW

Agricultural development in Vietnam has been shaped by economic reform, technological modernization, market integration, environmental pressure, and changing governance priorities. Existing scholarship commonly explains this transformation through three main pathways: high-tech agriculture, sustainable agriculture, and market-oriented agricultural development. Each pathway clarifies an important dimension of change, but none fully explains why climate adaptation outcomes differ across localities exposed to similar environmental pressures. For coastal delta regions such as the RRD, agricultural transformation should therefore be analyzed not only through productivity, sustainability, or market transition, but also through the local governance conditions that mediate adaptation.

The first pathway emphasizes high-tech and industrialized agriculture as a means of increasing productivity and competitiveness. This approach prioritizes mechanization, biotechnology, automation, digital information systems, and improved production efficiency. Tru et al. [12] argued that high-tech agriculture is necessary for Vietnam's deeper integration into global markets, while Gray and Jones [15] situated agricultural modernization within broader national development, noting constraints related to capital, infrastructure, and skilled labor. However, Giles et al. [16] cautioned that industrialized agriculture may favor large producers, accelerate land concentration, and marginalize smallholders. These concerns are especially relevant in delta regions where land fragmentation and unequal investment capacity remain common. Recent work on digitally enabled governance also suggests that technological modernization becomes effective only when supported by institutional redesign, decentralization, and implementation capacity [10].

The second pathway focuses on sustainable agriculture. Unlike productivity-centered models, this approach emphasizes ecological balance, resource conservation, long-term viability, and resilience to environmental shocks. World Bank [17] and Luyen and Kamoshita [18] advocated farming systems that promote soil conservation, biodiversity protection, reduced chemical inputs, organic agriculture, conservation farming, and integrated pest management. Gray and Jones [15] linked sustainable agriculture to green-economy strategies, arguing that environmental sustainability and economic restructuring must proceed together under climate change conditions. Nevertheless, implementation remains constrained by weak policy coordination, limited financial incentives, and insufficient technical extension

services. Phung and Dao [19] showed that farmers in the RRD increasingly understand sustainability as a practical means of risk reduction and adaptive capacity. Ichsan et al. [20] similarly indicated that sustainable farming practices must be embedded within eco-dynamic systems capable of responding to salinity, drought, and landscape-scale environmental change.

Recent interdisciplinary studies add a cultural and ethical dimension to sustainability debates in Vietnam. Nguyen et al. [21] connected sustainability values to Confucian educational philosophy, including moral self-cultivation, social responsibility, and harmony between humans and nature. Nguyen et al. [22] and Nguyen et al. [23] showed that Buddhist ecological ethics and faith-based stewardship can encourage environmentally responsible behavior. These perspectives help explain why local norms and collective responsibility matter for adaptation. However, cultural values alone cannot explain uneven adaptation outcomes unless they are connected to concrete governance arrangements, including planning, farmer training, infrastructure provision, credit access, and institutional support.

The third pathway concerns market-oriented agricultural transformation. World Bank [13] and Gray and Jones [15] argued that Vietnamese agriculture has moved from subsistence and self-sufficiency toward commodity production, value-chain integration, and market responsiveness. World Trade Organization (WTO) accession, Association of Southeast Asian Nations (ASEAN) integration, and bilateral trade agreements have reinforced this transition. Yet market integration can also produce unequal outcomes. World Bank [13] noted that price volatility, unequal bargaining power, and uneven regional development expose some farming households to new vulnerabilities. Nguyen et al. [11], using a SWOT-TOWS approach, further showed that agricultural transformation involves trade-offs between economic opportunity, environmental risk, and institutional capacity. This perspective is relevant because agricultural transformation cannot be evaluated only through output growth or market expansion; it must also be assessed through environmental exposure, governance readiness, and the ability of institutions to manage competing development pressures.

Across these three pathways, climate change functions as a disruptive force that reshapes agricultural development. In the coastal RRD, sea-level rise, salinity intrusion, drought, storm surges, and hydrological instability directly affect land productivity, water availability, and cropping systems. Yuen et al. [2] and Vu [3] documented the vulnerability of traditional rice-based farming systems because of their dependence on freshwater and fragile deltaic ecosystems. Islam et al. [24], drawing on evidence from major Asian deltas, showed how salinity affects rice systems and threatens agricultural livelihoods. Nguyen et al. [25] used machine-learning techniques to predict soil salinity in coastal Vietnam and identify districts such as *Thái Thụy* and *Kim Sơn* as areas of increasing risk. These studies establish the environmental basis of agricultural transformation, but they do not fully explain how local governance systems convert similar climate pressures into different adaptation outcomes.

The biophysical effects of climate change are closely linked to socio-economic transformation. Yuen et al. [2] emphasized that changes in temperature, radiation, and nutrient cycles threaten the biological limits of agricultural production. In practice, salinity intrusion reduces soil fertility, constrains rice cultivation, and encourages shifts toward aquaculture, salt-

tolerant crops, or integrated farming systems. Nong et al. [14] provided important evidence from *Tiền Hải* District, showing that cropland declined while aquaculture and mangrove areas expanded between 2000 and 2020. Their study is especially relevant because *Tiền Hải* is also one of the districts examined in the present article. However, Nong et al. [14] mainly focused on land-use change and household adaptation within one district through remote sensing and survey evidence. The present study builds on that work but differs by comparing six coastal districts and examining how district-level governance capacity mediates agricultural transformation.

Climate-driven restructuring also creates sustainability trade-offs. Carrión-Mero et al. [26] showed that aquaculture expansion can interact with mangrove ecosystems in ways that generate new ecological risks. This is important for coastal Vietnam because aquaculture may support income diversification while also increasing pressure on coastal ecosystems if poorly managed. Li et al. [27], by contrast, showed that integrated rice–aquaculture systems and alternate wetting-and-drying techniques can help maintain yields while reducing greenhouse-gas emissions. These studies indicate that adaptation strategies differ in long-term sustainability, depending partly on land-use regulation, water management, technical guidance, and environmental monitoring.

Farmer-level vulnerability further complicates adaptation. Vu [3] observed that many households in the coastal RRD lack the financial resources and institutional support needed for transformative adaptation. As a result, responses often remain reactive, including delayed planting, temporary production adjustment, or land abandonment. Luu et al. [28], using survey data from *Thái Thụy*, *Hải Hậu*, and *Kim Sơn*, showed that adaptation decisions are shaped by perceived risk severity, self-efficacy, and social norms. Luu et al. [28] similarly noted that although awareness of climate risks has increased, implementation remains uneven across households and localities. These findings suggest that awareness is necessary but insufficient; farmers also require timely information, technical knowledge, credit access, infrastructure support, and institutional coordination.

Governance therefore occupies a central position in the literature on agricultural adaptation. Giles et al. [16] emphasized state management, decentralization, and infrastructure investment in agricultural development. Fleischer et al. [29] showed that irrigation-water availability is a critical factor shaping agricultural vulnerability and adaptation under climate change, suggesting that water management and policy coordination are central to climate-resilient agricultural planning. Nguyen [30] identified weak coordination between central and local authorities as a major cause of delayed policy implementation. The World Bank [17] further argued that climate-smart agriculture depends on institutional alignment, farmer education, and public-private partnerships. Recent studies extend this view: Nguyen et al. [31] propose district-level coastal erosion strategies combining engineering and community participation; Nguyen et al. [32] documented changing climate patterns in the RRD; Jalali et al. [33] showed the value of scenario-based modelling for coastal land-use change; and Nguyen [34] linked ethical governance to participatory environmental management. Nguyen et al. [10] also show that lean, decentralized, and digitally enabled governance can improve responsiveness and coordination, a principle applicable to coastal agricultural adaptation.

Planning-oriented and inclusive-development research

further supports this governance perspective. Lai and Tran [9] demonstrated the importance of integrating spatial planning, social welfare, and sustainable development objectives in urban contexts. Although their study focuses on Ho Chi Minh City, the planning insight is relevant to coastal agricultural regions, where adaptation requires coordination among land use, infrastructure, livelihood support, and social equity. Nguyen [35], while focused on copyright exceptions and accessible knowledge for persons with disabilities, highlighted the broader importance of inclusive institutional design. In agricultural adaptation, this principle relates to farmers' access to extension services, climate information, technical assistance, and usable knowledge.

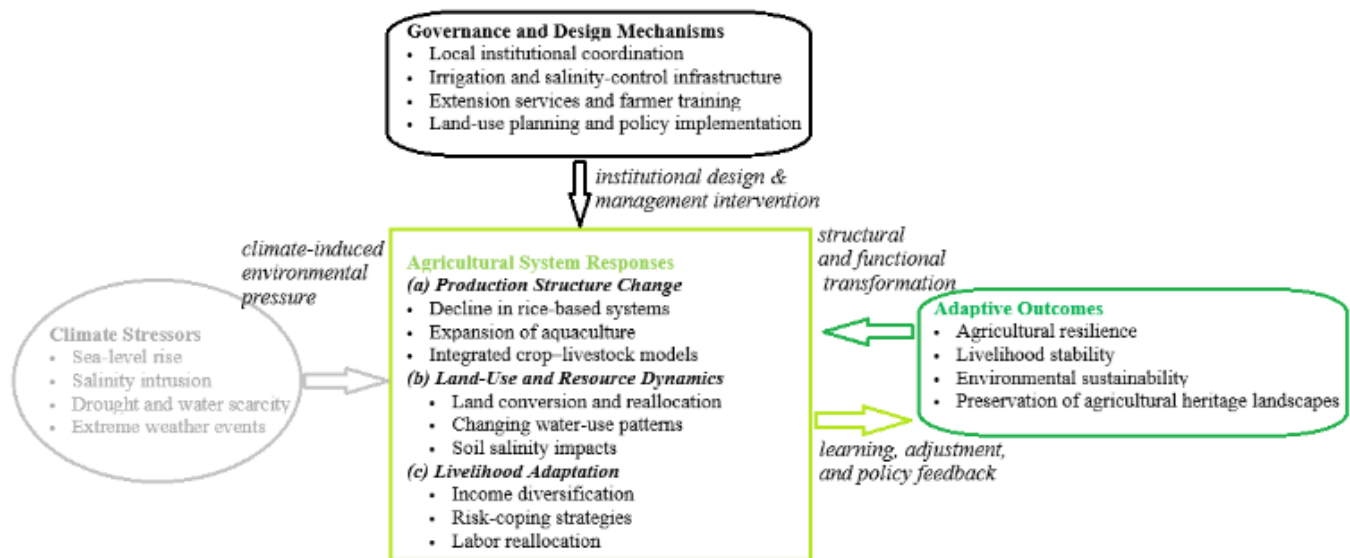
Comparative delta studies show that governance and infrastructure challenges are not unique to the RRD. Yuen et al. [2] and Phuong et al. [36] indicated that both the Red River and Mekong deltas face interacting pressures from land-use change, natural hazards, food security concerns, and institutional constraints. However, much of the existing literature remains region-wide, province-level, or focused on farmer behavior. Less attention has been given to district-level comparison within the same coastal delta, where ecological exposure and management decisions intersect most directly.

This gap is important because district authorities translate national policies into local action, coordinate infrastructure investment, organize extension services, manage land-use planning, and interact directly with farming communities. Neighboring districts may experience similar salinity, drought, and sea-level risks, but their adaptation outcomes may differ because their institutional capacities differ. Stronger irrigation systems, extension services, financial support, and administrative responsiveness can enable proactive transformation, while weak coordination, delayed policy support, and inadequate infrastructure can produce fragmented or reactive adaptation.

The present study therefore adopts a governance-mediated adaptation framework. Climate stressors such as salinity intrusion, sea-level rise, drought, and hydrological instability create pressure for agricultural restructuring. Production responses, including rice reduction, aquaculture expansion, crop–livestock integration, and livelihood diversification, represent observable adaptation outcomes. However, these outcomes are mediated by district-level governance conditions, including irrigation and salinity-control infrastructure, extension-service quality, financial support, technical guidance, planning coordination, and implementation capacity. By comparing six coastal districts, the study moves beyond documenting land-use change or farmer adaptation behavior and explains how governance capacity shapes uneven agricultural transformation in the coastal RRD.

### 3. METHODOLOGY

This study adopts a mixed-method research design to examine agricultural transformation in the coastal RRD of Vietnam under climate change conditions during 2010–2017. The design combines quantitative and qualitative evidence to capture both structural changes in agricultural production and the governance mechanisms shaping local adaptive responses. Conceptually, agricultural transformation is treated as a socio-ecological process shaped by the interaction among climate stressors, production-system responses, and district-level governance capacity.



**Figure 2.** Conceptual framework of climate-driven agricultural transformation in the coastal Red River Delta (RRD)

Note: The framework illustrates the interaction between climate stressors (e.g., salinity intrusion, sea-level rise, drought), agricultural system responses (production restructuring, land-use change, livelihood adaptation), and governance mechanisms (institutional coordination, infrastructure investment, extension services), which together shape adaptive outcomes and system resilience.

The study is guided by the conceptual framework presented in Figure 2. This framework links climate drivers, agricultural system dynamics, and governance mechanisms. Climate stressors such as salinity intrusion, sea-level rise, drought, and hydrological variability are treated as external pressures that influence agricultural restructuring. Agricultural responses include changes in cultivated area, crop yield, livestock output, aquaculture production, and rural income. Governance mechanisms include institutional coordination, infrastructure investment, salinity-control capacity, extension services, technical assistance, and policy implementation. This framework allows the study to examine not only what agricultural changes occurred, but also how governance conditions mediated adaptation across districts.

Quantitative data were compiled from official and publicly accessible sources, including provincial agricultural departments, statistical yearbooks, and government reports. The analysis focused on indicators of agricultural performance and transformation, including cultivated area, crop yield, livestock output, aquaculture production, and rural income levels. These indicators were examined longitudinally to identify changes in production structure, land use, and livelihood outcomes over time. The data were also used to compare district-level patterns of agricultural restructuring, especially shifts away from rice-dominated systems toward more diversified production models.

Qualitative data were collected through semi-structured interviews and structured questionnaire surveys. The study sites comprised six coastal districts exposed to sea-level rise, salinity intrusion, and extreme weather events: *Thái Thụy* and *Tiền Hải* in *Thái Bình* Province; *Giao Thủy*, *Hải Hậu*, and *Nghiã Hưng* in *Nam Định* Province; and *Kim Sơn* in *Ninh Bình* Province. These districts were selected because they share coastal climate risks but differ in ecological conditions, agricultural practices, infrastructure capacity, extension-service access, and local governance contexts. The inclusion of *Tiền Hải* is important because previous research has examined land-use change in this district; however, the present study places *Tiền Hải* within a six-district comparative design rather than treating it as a single case.

Semi-structured interviews were conducted with fifteen

local agricultural officials responsible for planning, extension services, or climate-related programs. Nine interviews were conducted face-to-face and six by telephone. The interview guide focused on institutional responses to climate stress, irrigation and salinity-control capacity, extension services, technical support, coordination between administrative levels, and barriers to policy implementation. All interviews were conducted with informed consent and transcribed for thematic analysis.

In parallel, a questionnaire survey was administered to 100 agricultural producers across the selected districts. The survey captured farmers' perceptions of climate change, observed impacts on agricultural production, adaptive practices, and access to technical, financial, or institutional support. Approximately one-quarter of the questionnaires were administered directly by the research team, while the remaining surveys were conducted by trained enumerators following standardized protocols.

Survey responses were coded and analyzed using Microsoft Excel. Descriptive statistics were used to identify patterns in climate awareness, adaptive behavior, production adjustment, and livelihood responses. Quantitative indicators, interview themes, and survey findings were then triangulated to compare adaptation dynamics across the six districts. This triangulation enabled the study to assess whether differences in agricultural restructuring corresponded with differences in governance conditions, including infrastructure provision, extension-service effectiveness, technical or financial support, and local coordination capacity.

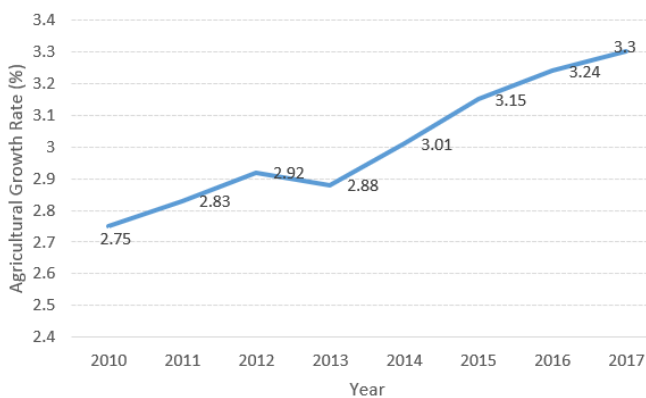
Overall, this mixed-method design, anchored by the conceptual framework in Figure 2, provides a transparent basis for examining climate-adaptive agricultural transformation in coastal socio-ecological systems. Its main methodological contribution is to connect longitudinal agricultural indicators with district-level governance evidence and farmer-reported adaptation experiences. This design supports the study's central argument that agricultural transformation in the coastal RRD is not merely a land-use response to climate stress, but a governance-mediated adaptation process that varies across local institutional contexts.

## 4. RESULTS AND DISCUSSION

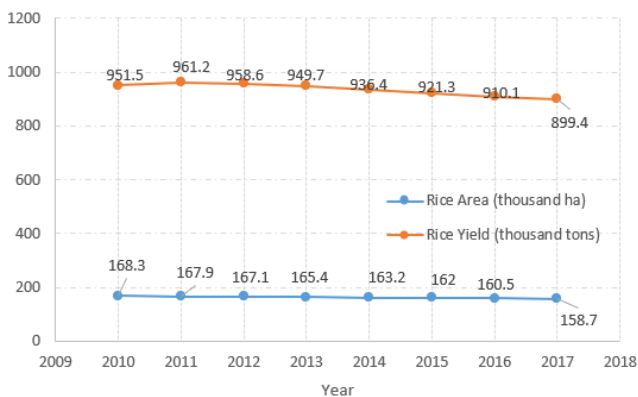
### 4.1 Agricultural restructuring under climate pressure

Quantitative evidence from the coastal RRD shows that agricultural transformation during 2010–2017 occurred under simultaneous conditions of moderate growth and increasing climate pressure. Overall agricultural growth increased from 2.75% in 2010 to 3.30% in 2017, indicating that the regional agricultural system retained a degree of productive resilience despite environmental stress (Figure 3). However, this growth should not be interpreted as simple continuity. Rather, it reflects structural adjustment within the agricultural system, as traditional rice-based production became increasingly constrained by salinity intrusion, freshwater instability, and hydrological variability.

The clearest evidence of restructuring appears in the decline of rice cultivation. As shown in Figure 4, the total rice-growing area decreased from 168.3 thousand hectares in 2010 to 158.7 thousand hectares in 2017, while rice production fell from 951.5 thousand tons to 899.4 thousand tons. This decline confirms earlier findings that rice-based systems in the coastal RRD are vulnerable to salinity intrusion, drought, and reduced freshwater availability [1, 3]. The result is important because it shows that agricultural transformation in the region is not merely a market-led modernization process; it is also a climate-driven response to the declining ecological stability of rice-based production.



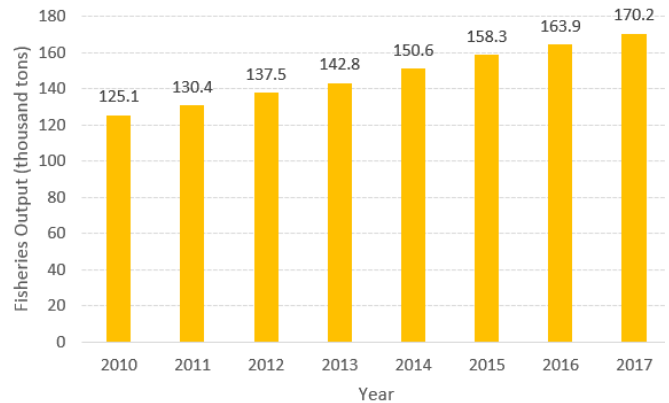
**Figure 3.** Agricultural growth rate (%) in the coastal Red River Delta (RRD) (2010–2017)



**Figure 4.** Decline in rice cultivation area and yield (2010–2017)

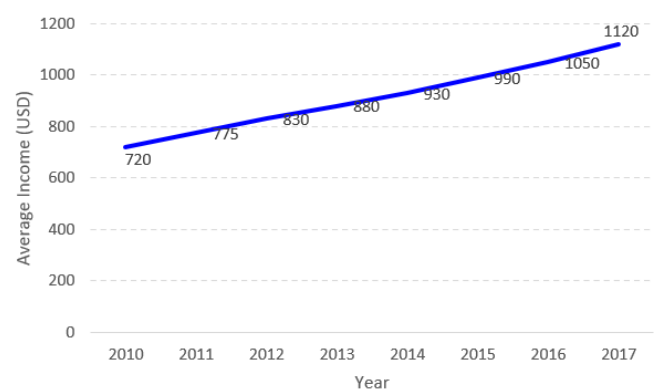
By contrast, fisheries production increased substantially

during the same period. Total fisheries output rose from 125.1 thousand tons in 2010 to 170.2 thousand tons in 2017 (Figure 5). This expansion reflects a shift from rice-dominated agriculture toward aquaculture and other diversified coastal production systems. The pattern is consistent with Nong et al. [14], who found that cropland in *Tiền Hải* District declined while aquaculture and mangrove areas expanded under the combined influence of environmental pressure and economic adaptation. However, the present study extends this finding by showing that aquaculture expansion is part of a broader regional transformation across several coastal districts, not only a land-use change observed in *Tiền Hải*.



**Figure 5.** Rising fisheries output and shifting agricultural structure (2010–2017)

Rural income also increased during the study period. Average per capita income rose from approximately USD 720 in 2010 to USD 1,120 in 2017 (Figure 6). This suggests that livelihood diversification, especially through aquaculture and mixed production models, contributed to income improvement. The finding is consistent with earlier arguments that market-oriented agricultural transformation can support rural income growth [13, 16]. Nevertheless, income growth does not mean that adaptation was equally successful across districts. The key analytical issue is not whether the coastal RRD experienced agricultural growth, but why the benefits and adaptive capacity associated with this transformation were unevenly distributed across localities.



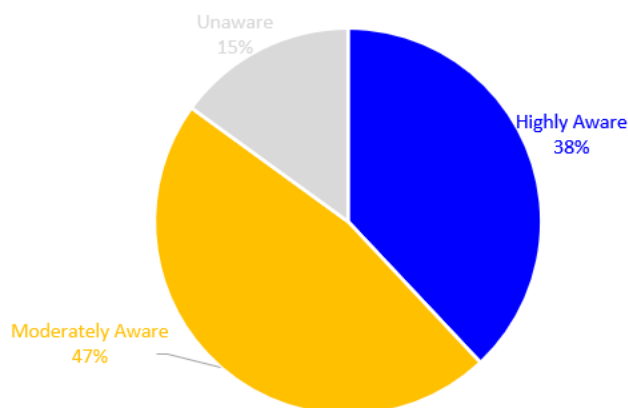
**Figure 6.** Average income per capita (2010–2017)

Taken together, Figures 3–6 show a shift from rice-centered agriculture toward more diversified production structures. This transition reflects an eco-dynamic adaptation process in which environmental stress, market opportunity, and local governance interact. The decline of rice cultivation indicates

ecological constraint, while the expansion of fisheries and rising rural income suggest adaptive restructuring. Yet such restructuring also creates sustainability risks. Aquaculture can support income diversification, but poorly managed expansion may generate pressure on mangrove ecosystems and coastal environments, as noted by Carrión-Mero et al. [26]. Conversely, integrated rice–aquaculture systems and alternate wetting-and-drying techniques may align adaptation with mitigation and productivity goals [27]. The sustainability of agricultural transformation therefore depends not only on farmers’ production decisions but also on local governance capacity in land-use regulation, water management, technical guidance, and environmental monitoring.

#### 4.2 Farmer awareness and adaptive production models

Survey results provide further evidence that agricultural transformation is linked to changing farmer perceptions and adaptive behavior. As shown in Figure 7, 38% of respondents reported a high level of awareness of climate-related impacts, while 47% reported moderate awareness. Only 15% indicated little or no awareness. This distribution suggests that climate-risk information has reached many farming households, possibly through local experience, extension activities, and public communication. However, the presence of a low-awareness group also indicates that knowledge dissemination remains incomplete.

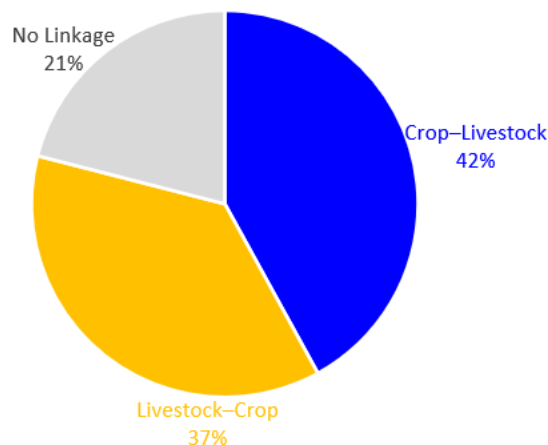


**Figure 7.** Farmers’ perception of climate change risks

These findings support Luu et al. [28], who argue that adaptation decisions in the RRD are shaped by perceived risk severity, self-efficacy, and social norms. They are also consistent with Phung and Dao [19], who show that farmers increasingly understand sustainability in practical terms as a means of reducing risk. However, awareness alone does not guarantee effective adaptation. Farmers require technical assistance, financial support, infrastructure, and policy guidance to convert awareness into feasible production changes. This helps explain why adaptation remains uneven even when climate-risk perception is relatively widespread.

Patterns of production integration further demonstrate the emergence of adaptive farming models. Among surveyed households, 42% reported adopting crop–livestock integration, while 37% applied livestock–crop systems. The remaining 21% had not integrated production activities (Figure 8). These results suggest that integrated farming is becoming an important adaptation pathway. Such models can diversify income sources, reduce dependence on rice monoculture, and improve household resilience under climate

uncertainty. They also support sustainable-agriculture approaches advocated by World Bank [17], Luyen and Kamoshita [18], and Ichsan et al. [20], especially where soil, water, and production management are coordinated within a broader system.



**Figure 8.** Integration patterns in agricultural production models

At the same time, the 21% of households without integrated production indicates that barriers remain. These barriers may include limited capital, fragmented landholding, insufficient technical knowledge, weak cooperative arrangements, and uneven access to extension services. Luu et al. [28] similarly observed that awareness of climate risk does not always lead to consistent implementation of adaptation measures. The survey findings therefore reinforce the governance-mediated adaptation argument: farmer awareness and willingness are necessary, but adaptation depends on whether local institutions provide the enabling conditions for practical change.

Climate projections under the Representative Concentration Pathway 4.5 (RCP4.5) scenario further underline the urgency of strengthening adaptive capacity. By 2030, sea level is projected to rise by approximately 28–33 cm, salinity intrusion may expand 5–10 km inland, average temperature may increase by 1.5 °C, and drought frequency may double compared with 2010 levels (Table 1). These projections suggest that the pressures already visible during 2010–2017 are likely to intensify. Adaptation strategies therefore need to move beyond short-term adjustment toward long-term climate-resilient agricultural planning.

**Table 1.** Projected climate change impacts under Representative Concentration Pathway 4.5 (RCP4.5) scenario by 2030

Impact Type	Projection to 2030
Sea level rise	+28–33 cm
Salinity intrusion	Expands 5–10 km inland
Temperature increase	+1.5 °C
Drought frequency	Increased 2× from 2010 levels

Source: Authors, 2025.

The projected expansion of salinity intrusion and drought is especially important for districts dependent on freshwater irrigation and rice cultivation. Scenario-based studies suggest that spatial planning decisions can generate cumulative environmental feedback that either reinforces or undermines

adaptation outcomes [33]. Thus, agricultural zoning, irrigation investment, aquaculture expansion, and land-use conversion should be evaluated through an integrated planning framework rather than through isolated sectoral interventions.

### 4.3 District-level comparison of governance-mediated adaptation

Qualitative evidence from interviews with local officials and farmer surveys shows that adaptation capacity differs across the six districts. This district-level comparison is the main empirical contribution of the study beyond Nong et al. [14]. While Nong et al. [14] documented land-use change and household adaptation in *Tiền Hải* District, the present study compares six districts and shows how governance capacity, infrastructure, extension services, technical support, financial assistance, and local coordination shape uneven adaptation outcomes.

Officials across the study area identified salinity intrusion and prolonged drought as major threats to agricultural production. However, their accounts also revealed important differences in local capacity. In *Thái Thủy* and *Giao Thủy*, officials emphasized limitations in irrigation infrastructure and salinity regulation. These constraints reduce the ability of local authorities and farmers to stabilize freshwater supply during dry seasons. In *Kim Sơn*, officials highlighted rising input costs and changing rural labor availability, indicating that climate pressure interacts with broader socio-economic constraints. Farmers in *Tiền Hải* and *Hải Hậu* generally reported better access to technical training, extension services, and financial support, allowing more proactive adaptation. By contrast, farmers in *Nghĩa Hưng* frequently described limited institutional assistance and delayed policy support.

Table 2 shows that climate exposure alone does not explain adaptation outcomes. Districts facing similar environmental pressures respond differently because their governance

conditions differ. *Tiền Hải* and *Hải Hậu* appear to have stronger adaptive conditions because farmers reported better access to training, extension services, and financial support. These enabling conditions make it easier for households to adopt diversified production models and respond proactively to climate risk. By contrast, *Thái Thủy* and *Giao Thủy* illustrate the constraining role of irrigation and salinity-control limitations. Even when farmers recognize climate threats, adaptation remains difficult if water-management infrastructure is inadequate. *Nghĩa Hưng* shows how delayed institutional assistance can produce more reactive adaptation, while *Kim Sơn* demonstrates that environmental pressure may be intensified by rising input costs and labor changes.

These findings refine earlier work on climate adaptation in the RRD. Yuen et al. [2] and Vu [3] showed that climate change disrupts traditional agricultural systems, while Luu et al. [28] emphasized farmer perception and behavioral intention. The present study adds that adaptation is mediated by district-level governance capacity. This means that the same climate stressor may produce different outcomes depending on whether local authorities can coordinate infrastructure, provide technical guidance, mobilize support, and implement policies effectively.

The findings also challenge linear assumptions about policy implementation. Existing policies may promote climate-smart agriculture, land-use adjustment, or rural development, but their effectiveness depends on local coordination. Nguyen [30] identified weak coordination between central and local authorities as a persistent barrier to agricultural development. The World Bank [17] similarly emphasized that climate-smart agriculture requires institutional alignment, farmer education, and public-private partnerships. Evidence from the six districts confirms that adaptation is not automatic once policies exist. It depends on whether district institutions can translate policy objectives into practical support for farmers.

**Table 2.** District-level governance conditions and adaptation outcomes across six coastal districts

District	Main Climate Pressure	Dominant Agricultural Transformation	Governance/Infrastructure Condition	Adaptation Outcome	Main Constraint
<i>Thái Thủy</i>	Salinity intrusion, drought, freshwater instability	Rice pressure and gradual diversification	Irrigation and salinity-control limitations reported by officials	Adaptation occurs but remains constrained by water-control capacity	Insufficient irrigation infrastructure
<i>Tiền Hải</i>	Salinity intrusion, land-use pressure, coastal exposure	Aquaculture expansion and diversified farming	Relatively better access to technical and financial support	More proactive adaptation compared with weaker-support districts	Need to manage aquaculture-related ecological trade-offs
<i>Giao Thủy</i>	Salinity intrusion and unstable freshwater supply	Crop adjustment and mixed production systems	Irrigation limitations affect local response capacity	Adaptation is partly constrained by infrastructure	Limited freshwater regulation
<i>Hải Hậu</i>	Climate variability and production risk	Diversified and integrated farming models	Better extension-service and support access reported by farmers	Relatively stronger farmer response and adaptive behavior	Continued need for coordinated technical support
<i>Nghĩa Hưng</i>	Climate risk, delayed support, limited assistance	Slower and more constrained adaptation	Weak institutional support and delayed policy assistance	More reactive adaptation	Limited extension and financial support
<i>Kim Sơn</i>	Salinity risk, input-cost pressure, rural labor change	Diversification under socio-economic pressure	Governance challenge linked to cost and labor constraints	Adaptation shaped by both environmental and economic stress	Rising input costs and labor availability

The comparison also supports broader delta studies. Yuen et al. [2] and Phuong et al. [36] showed that both the Red River and Mekong deltas face interacting pressures from land-use change, natural hazards, and food security challenges. However, this study shows that intra-regional variation is equally important. Within the coastal RRD itself, adaptation outcomes differ across districts because governance arrangements, infrastructure quality, and farmer-support mechanisms are uneven. The study therefore advances the literature by identifying governance-mediated adaptation as a causal mechanism linking climate pressure, production restructuring, and local institutional capacity.

#### 4.4 Policy implications for climate-resilient agricultural governance

The findings suggest that sustainable agricultural development in the coastal RRD requires a governance framework oriented toward resilience, coordination, and long-term planning. The central implication is that climate-smart agriculture should be treated as an institutional reform process, not merely as a technical intervention. Production diversification, aquaculture development, integrated farming, and climate-resilient crops can improve adaptive capacity only when supported by infrastructure, extension services, financial instruments, and effective local coordination.

First, climate-informed agricultural zoning should be strengthened. The projected impacts in Table 1 indicate that salinity intrusion, sea-level rise, and drought will increasingly affect land suitability. Districts should use climate-risk assessments to guide crop selection, aquaculture expansion, irrigation planning, and land-use conversion. This is especially important in areas where rice cultivation is becoming less viable. However, land-use conversion should be managed carefully to avoid ecological trade-offs, particularly where aquaculture expansion affects mangrove systems or coastal water quality.

Second, investment in localized infrastructure remains essential. Irrigation systems, salinity-control structures, drainage networks, sea dykes, and flood-protection infrastructure are central to adaptation. The experiences of *Thái Thủy* and *Giao Thủy* show that weak water-control capacity can constrain agricultural restructuring even when farmers are aware of climate risks. Infrastructure investment should therefore be coordinated across district boundaries because salinity, water flow, and flood risk do not follow administrative borders. Integrated regional planning can reduce duplication, improve resource allocation, and strengthen collective resilience.

Third, extension services and farmer education should be expanded, especially in districts with weaker support systems. The survey results in Figures 7 and 8 indicate that many farmers are aware of climate risk and some are already adopting integrated production models. However, the uneven distribution of support shows that awareness must be matched with practical assistance. Extension programs should provide guidance on salt-tolerant crops, integrated crop-livestock systems, aquaculture management, soil and water conservation, and market-risk management. Particular attention should be given to *Nghĩa Hưng* and other areas where farmers reported limited institutional assistance.

Fourth, financial instruments should be better aligned with adaptation needs. Credit schemes, targeted subsidies, tax incentives, agricultural insurance, and support for cooperative

models can reduce the cost of transition for smallholders. Evidence from Israeli agriculture shows that irrigation-water availability and related policy conditions play a critical role in shaping agricultural vulnerability and adaptation under climate change [29], and the present findings confirm the relevance of linking financial support with water management, infrastructure investment, and cross-sectoral planning. Without financial support, households may recognize climate risks but remain unable to invest in new production models, technologies, or infrastructure.

Fifth, district-level coordination should be strengthened through regional planning mechanisms. Fragmented local responses reduce policy effectiveness, especially in coastal zones where irrigation systems, salinity intrusion, aquaculture development, and flood protection are interconnected. Enhanced coordination among *Thái Thủy*, *Tiền Hải*, *Giao Thủy*, *Hải Hậu*, *Nghĩa Hưng*, and *Kim Sơn* could support shared investment, information exchange, joint monitoring, and collective risk management. This would help transform adaptation from a set of localized responses into a coherent regional strategy.

Finally, agricultural adaptation should be linked with broader Sustainable Development Goals. The coastal RRD is not only a production space but also a socio-ecological and cultural landscape. Adaptation policies should therefore balance income improvement, food security, ecosystem protection, and rural livelihood stability. Nature-based solutions such as mangrove restoration, combined with appropriate aquaculture regulation and irrigation planning, can support both ecological resilience and livelihood adaptation.

Overall, the results demonstrate that agricultural transformation in the coastal RRD is neither uniform nor purely climate-determined. The region is moving away from rice-dominated systems toward more diversified production, but the effectiveness of this transition depends on district-level governance capacity. By comparing six districts, this study shows that governance-mediated adaptation provides a clearer explanation of uneven outcomes than land-use change analysis alone. Sustaining progress will require integrated land-use planning, localized infrastructure investment, stronger extension systems, accessible finance, and inter-district coordination. These measures can help guide the coastal RRD toward a more resilient and sustainable agricultural future.

## 5. CONCLUSION

This study examined climate-driven agricultural transformation in Vietnam's coastal RRD during 2010-2017, focusing on six coastal districts: *Thái Thủy*, *Tiền Hải*, *Giao Thủy*, *Hải Hậu*, *Nghĩa Hưng*, and *Kim Sơn*. The findings show that agricultural development in the region has evolved as a systemic response to sustained climate stress, including sea-level rise, salinity intrusion, drought, and hydrological variability. The region experienced moderate agricultural growth and rising rural income, but these gains occurred alongside a clear decline in rice cultivation and a shift toward more diversified production systems, especially aquaculture and integrated crop-livestock models.

The main contribution of this study is its governance-mediated district comparison. While previous research, especially Nong et al. [14], has documented climate-driven land-use change and household adaptation in *Tiền Hải* District, the present study extends the analysis by comparing six coastal

districts and explaining why adaptation outcomes differ across localities exposed to similar climate pressures. The findings show that agricultural transformation is not determined by environmental stress alone. Rather, adaptation is mediated by district-level governance conditions, including irrigation and salinity-control infrastructure, extension services, technical support, financial assistance, institutional coordination, and local implementation capacity.

The comparative findings indicate that *Tiền Hải* and *Hải Hậu* show relatively stronger adaptation conditions due to better access to training, extension services, and support mechanisms. By contrast, *Thái Thủy* and *Giao Thủy* remain constrained by irrigation and salinity-control limitations, *Nghĩa Hưng* faces weaker institutional assistance and delayed policy support, and *Kim Sơn* illustrates how climate pressure interacts with rising input costs and labor changes. These differences demonstrate that climate-resilient agriculture requires more than technical adjustment or market-led diversification. It requires locally responsive governance capable of converting climate awareness, infrastructure investment, and farmer support into practical adaptation outcomes.

The study has several limitations. First, the temporal scope covers 2010–2017 and therefore does not capture more recent climate events, policy reforms, digital-governance initiatives, or post-2017 agricultural restructuring. Second, the survey sample of 100 producers and interviews with 15 local officials provide useful district-level insights but may not fully represent all farmer groups, especially migrant workers, landless households, marginal producers, cooperatives, private firms, and non-governmental actors. Third, the study relies mainly on descriptive quantitative indicators and qualitative interpretation; it does not employ econometric modelling, spatial remote-sensing analysis, or causal impact evaluation.

Future research should extend the dataset beyond 2017 to assess more recent adaptation dynamics and policy outcomes. Comparative studies with other vulnerable regions, especially the Mekong Delta, would help clarify whether governance-mediated adaptation operates similarly across different delta systems. Further research should also incorporate spatial data, remote sensing, econometric analysis, and larger household surveys to test the relationship between governance capacity and adaptation outcomes more rigorously. Finally, greater attention should be given to digital technologies, precision agriculture, private-sector participation, cooperative models, nature-based solutions, and intergenerational knowledge transfer in shaping long-term climate-resilient agricultural development.

In conclusion, the study shows that agricultural adaptation in the coastal RRD is best understood as a governance-mediated socio-ecological process. Sustainable transformation depends on aligning environmental dynamics, production restructuring, infrastructure planning, extension services, and district-level institutional capacity. Strengthening inter-district coordination and locally responsive governance will therefore be essential for guiding the coastal RRD toward a more resilient and sustainable agricultural future.

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