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Collaborative and Social Ecological Governance for Attaining Shared Capacity and Coastal Community Resilience in West Sumatra, Indonesia

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Abstract: Climate change poses significant challenges for developing countries, where coastal communities are the most vulnerable. However, adaptation policies targeting coastal populations often remain ineffective because top-down governance structures fail to integrate social-ecological systems adequately. This study empirically examined an integrated Collaborative Governance-Social Ecological Systems (CG-SES) model encompassing principled engagement, shared capacity, joint action, multi-level fit, and community resilience. The analysis was based on the survey data collected through a structured questionnaire from 411 coastal residents in Padang City, Pesisir Selatan Regency, and the Mentawai Islands Regency, West Sumatra. Partial Least Squares-Structural Equation Modelling (PLS-SEM) was employed to assess relationships among various governance dimensions and resilience outcomes. The results indicated that principled engagement had a positive and significant effect on shared capacity (β = 0.936, p < 0.001) and community resilience (β = 0.651, p < 0.001). Shared capacity also positively influenced joint action (β = 0.472, p < 0.001) and community resilience (β = 0.342, p < 0.001). These relationships enhanced the predictive power of the model (R^2 = 0.926 for multi-level fit; R^2 = 0.941 for community resilience), indicating that governance variables explained a substantial proportion of variation in resilience outcomes. The findings further suggested that shared capacity functioned as a key mediating mechanism linking principled engagement to community resilience. At the same time, multi-level fit and joint action did not demonstrate direct or moderating effects. Overall, the results highlight the importance of co-produced knowledge, institutional trust, and collective capacity in shaping climate adaptation outcomes in the coastal regions of the Global South.

Keywords: Collaborative governance; Social-ecological resilience; Shared capacity; Climate adaptation; Coastal communities; Partial Least Squares-Structural Equation Modelling

1. Introduction

Coastal regions are highly vulnerable to the impacts of climate change, particularly in developing countries where institutional capacity and adaptive resources are often limited. Along Indonesian coastlines, climate-induced shoreline erosion, tidal flooding, and increasingly frequent extreme wave events pose serious threats to livelihoods and coastal ecosystems. In West Sumatra, areas such as Padang City, Pesisir Selatan Regency, and the Mentawai Islands Regency are among the most affected, as they experience persistent ecological stress that undermines both environmental sustainability and socioeconomic resilience (BAPPENAS, 2021; BRIN, 2023). These conditions underscore the urgent need to strengthen community resilience in coastal areas with high exposure to climate-related hazards.

Despite this urgency, policies related to climate adaptation in many developing countries continue to be predominantly shaped by top-down governance approaches. Such approaches often marginalize local actors and limit meaningful community participation in decision making. As a result, initiatives of adaptation frequently fail to reflect local needs, knowledge systems, and socioeconomic realities. Global assessments indicate that a substantial proportion of adaptation efforts are undermined by weak participation and ineffective governance arrangements (Putera et al., 2019; United Nations Office for Disaster Risk Reduction, 2023). In the Indonesian context, adaptation policies remain largely bureaucratic and are often implemented through standardized frameworks that inadequately account for the live experiences of coastal communities dependent on marine-based livelihoods (Nurhidayah & McIlgorm, 2019). This misalignment contributes to fragmented implementation of policies and suboptimal adaptation outcomes.

In response to these challenges, collaborative governance integrated with social-ecological systems has emerged as a prominent transdisciplinary framework for addressing complex environmental problems (Valentina et al., 2025). This approach emphasizes stakeholder engagement, collective action, and the co-production of knowledge as key mechanisms for enhancing adaptive capacity and resilience within the framework of Collaborative Governance-Social Ecological Systems (CG-SES). Social mobilization functions as a critical linkage connecting governance processes with adaptive outcomes, thus enabling positive feedback loops that support the building of resilience (Berkes & Ross, 2013). Importantly, this perspective highlights that resilience is shaped not only by formal institutional arrangements but also by relational processes such as trust, communication, and shared understanding among actors operating across various governance levels.

This study drew on primary data collected in 2025 from 411 coastal residents in Padang City, Pesisir Selatan Regency, and the Mentawai Islands Regency. A stratified random sampling strategy was employed to ensure representation across diverse coastal settlements. Before analysis, the dataset was screened for missing values and outliers, with no substantial reduction in the sample size. Missing data were randomly distributed and handled using listwise deletion, thus yielding a final analytic sample of 411 respondents. Preliminary observations suggested that cooperative processes that emphasized broad participation and strengthened collective capacity played a central role in shaping the resilience of the community.

Interestingly, the findings also indicated that certain dimensions commonly associated with collaborative governance, such as formalized collective action and vertical administrative alignment, exerted limited Influence on this context. This suggested that, for coastal communities in West Sumatra, relational and communicative processes might be more influential than structural coordination across governance levels. These results challenged prevailing assumptions in the literature that coordination and multi-level alignment inherently led to improved resilience outcomes.

By empirically linking collaborative governance with social-ecological systems, this study contributes to ongoing theoretical debates on climate adaptation and resilience. The findings indicated that, in disaster-prone coastal contexts, resilience was more effectively fostered through trust-building, inclusive dialogue, and collaborative knowledge production than through rigid or hierarchical governance arrangements. This underscored the importance of situating collaborative governance within the specific socio-political contexts of coastal communities (Adger et al., 2022; Pahl-Wostl, 2009).

Methodologically, the study employed Partial Least Squares-Structural Equation Modelling (PLS-SEM) using SmartPLS 4 to examine relationships among latent variables characterised by reflective indicators and non-normal data distributions. A total of 48 indicators measuring governance and resilience dimensions were assessed using a five-point Likert scale. The analysis focused on respondents residing within two kilometres of the coastline, to reflect their direct exposure to coastal risks. Accordingly, the study did not generalise beyond coastal communities with similar characteristics of exposure.

Overall, this study examined the effects of key collaborative governance components such as principled engagement, shared capacity, joint action, and multi-level fit on community resilience in coastal West Sumatra. By integrating collaborative governance and social-ecological systems through primary empirical data, the study offers theoretical and practical insights for policymakers, local governments, and non-governmental organisations seeking to design more inclusive and context-sensitive climate adaptation strategies in vulnerable coastal regions.

2. Methodology

2.1 Study Area

Research was conducted in three coastal areas of West Sumatra: Padang City, Pesisir Selatan Regency, and the Mentawai Islands Regency, all within 2 km of the coastline, as shown in Figure 1. Selection of these areas was due to maximising heterogeneity, which ensures a comprehensive understanding of the specific institutional arrangements, environmental concerns, and socioeconomic systems. Realising the diversity of control systems within an administrative governance system of a particular region is crucial for determining the guiding features of diversity across systems of governance, culture, livelihoods, and ecosystems.

To provide the background on the environmental challenges faced by communities, one could refer to coastal erosion and shoreline retreat in Pantai Salido, Pesisir Selatan Regency, which have resulted in land loss, damage to residential areas, and damage to public infrastructure. Assessments of recent coastal change indicate substantial shoreline retreat along the West Sumatran coast. In Padang City, approximately 66% of the coastline has experienced erosion, with shoreline retreat rates ranging from 0.21 to 49.4 meters per year, based on the analysis from Digital Shoreline Analysis System (DSAS) (Wisha et al., 2022). Furthermore, long-term regional monitoring indicates that West Sumatra loses approximately 56.3 hectares of coastal land annually due to the processes of abrasion (Maulana & Prarikeslan, 2024). These physical changes have significant socioeconomic consequences for coastal communities, particularly small-scale fishers, as coastal abrasion disrupts fishing infrastructure, reduces livelihood stability, and forces households to adapt or relocate (Bagindo et al., 2023).

Figure 1. Study area in West Sumatra, Indonesia
Source: Natural Earth; Badan Informasi Geospasial (BIG); GADM v4.1. (2026).

Figure 2 reflects the phenomenon and the resulting land loss and damage to public infrastructure. Economically, small-scale fishing operators lose their income or, at the very least, face a significant income loss, as evidenced by the damage to fishing vessels due to high waves (see Figure 3). This phenomenon provides the communities with climate perturbations, when abided by the analytics of the CG-SES model.

Adding to the documented elements of the environment and the images, Table 1 provides information on the institutions, environment, and economy of the researched sites and describes the differences in environmental governance, risk factors, and community adaptive strategies in the three studied sites, in order to demonstrate the complex conditions under which integrated governance approaches are applied.

A description of the unique institutional and socio-ecological differences across the studied sites is provided in an aggregated form in Table 1, which provides an overview of each site in terms of local governance, ecological risk, and socioeconomic structure. It captures the breadth of the sites with respect to governance, collaboration, and partnerships, hence reflecting the institutional and social-ecological complexities of the sites.

The merging of these three distinct regions provides an excellent basis for analysing the concomitant governance of several coastal areas. In analysing the range of institutional differences, the division between local governance and modern urban regional planning, and between the spatial planning of local political units and traditional civil village governance, is reflected in the examination of the variables of participation, trust, and joint action. This is an important element in the theory of collaborative governance; it is assumed that the variables of participation, collaborative capacity, and joint action will differ as local governance structures become thorough and more sophisticated.

Figure 2. Abrasion at Pantai Salido, Pesisir Selatan Regency
Source: Based on the Field Data.

Figure 3. Fishing boats damaged by high waves
Source: Based on the Field Data.

Table 1. Social-ecological dimensions of the study sites

Location	Local Governance Form	Characteristics of Ecological Risk	Socioeconomic Characteristics
Padang City	Kelurahan	Effects of abrasion and tidal flooding associated with land conversion along the coast	Economy of the urban coast; trade and services
Pesisir Selatan Regency	Nagari	Effects of sedimentation and mangrove degradation from upstream	Fisheries in the coastal rural area; small-scale capture fishing
The Mentawai Islands Regency	Desa (Customary village)	Rise in the sea level and storms	Isolation of the archipelago; customary fisheries

The differences in ecology in the chosen sites further enriched the inquiries of research. This research was aptly placed in regions with varying challenges related to climate change, as the study was particularly appropriate for understanding the development of resilience when communities addressed specific forms of environmental stress. It is this difference that is essential in determining whether collective efforts enhance resilience the same way across divergent hazard environments, or whether their effect is limited to certain contextual circumstances.
The socioeconomic and geographical diversity of the city and the country, and the remote areas within the study area, added analytical strength through contrasts and comparisons. The structuring of the communities' collaboration and participatory activities in governance systems was defined by their economic stability, resource base, and economic diversification. Such characteristics illustrated the CG-SES framework by demonstrating the extent to which the social and economic variables of a system could impact the governance-resilience nexus.

In addition to their heterogeneity, the selected regions have strategic importance, as they are high-risk areas in the Indonesian Disaster Risk Index (BNPB, 2024), rendering them especially well-suited for studying the processes of building resilience in the areas and the most severe impacts. Methodologically, the choice of these three sites also ensured an adequate level of information power (Malterud et al., 2016), enabling the study of the cases in greater detail with minimal geographical spread. This, in turn, increased the coherence of the findings and their applicability to other similar coastal areas in West Sumatra. Within these methodological boundaries, empirical analysis was conducted using a pooled dataset to examine the overall relationships between governance and resilience in high-risk coastal areas. As a result, possible differences across the regions that should have been examined more closely were not addressed, which remains a limitation of the study.

In conclusion, the three study sites offered strategically integrated scopes for assessing the CG-SES model. Their combined institutional, ecological, and socioeconomic aspects provided valuable contexts for assessing and working with governance models of coastal population resilience. This allows the present research to generate recommendations relevant to a wide spectrum of coastal adaptation approaches.

2.2 Data Collection

Data collection was conducted between August and October 2025 through semi-structured interviews, field observations, and document review. Data collection for the study began with one survey, which included a sample of 411 residents living in the coastal areas of Padang City, Pesisir Selatan Regency, and the Mentawai Islands Regency. The respondents in the sample were drawn from specific geographical locations, hence the adoption of a quantitative survey technique. According to the author of this study, the sample size was expected to be proportional to the population size based on the PLS-SEM analyses. The coastal location was also stratified for selection in a district-nested sampling technique to facilitate sample reflection drawn from the three coastal zones. To achieve sample balance and heterogeneity, and to preserve proportionality in the dominant and smaller groups vis-a-vis age, sex, and socioeconomic status, a systematic random sampling was performed across the grouped district units (Creswell & Plano Clark, 2018). Such principles of sample design strengthened the internal and external validity of the results.

In this case, the CG framework (Ansell & Gash, 2008; Emerson et al., 2012) and SES framework (Folke et al., 2010; Ostrom, 2010) were adopted on community resilience (Berkes & Ross, 2013; Norris et al., 2008) as the baseline for the survey. Such data collection required meticulous attention to coherence between the theoretical framework and the empirical elements.

All materials were assessed using a five-point Likert scale, where 1 indicates "disagree strongly" and 5 indicates "agree strongly". This is a common approach to analysing perceptions, governance processes, and resilience indicators in social-ecological studies. Before the application of the framework on a larger scale, the survey instrument was validated by several experts. A pilot test was conducted to improve item clarity and ensure alignment with the theory.

The process of data collection adhered to ethical and methodological concerns as far as possible. Participants in the data collection process were informed of the purpose of this study; they could leave the study at any time without consequences and without any obligations to participate. All data was kept confidential and stored in password-protected and digitally encrypted files. Ethical approval was not obtained for this study. Nevertheless, the research adhered to ethical principles, including voluntary participation, confidentiality, and informed consent. Construct validity was analysed theoretically and bio-statistically. At the same time, reliability was established and demonstrated using Cronbach's Alpha (α), Composite Reliability (*CR*) and Average Variance Extracted (AVE), which all exceeded the expected levels for the variables measured ($\alpha > 0.70$; $CR > 0.70$; AVE > 0.50) (Nunnally & Bernstein, 1994).

In accordance with the standards of social-ecological research, data credibility was enhanced through member checking, peer debriefing, and an audit trail (Lincoln & Guba, 1985). Member checking was conducted by sharing key interpretations of the survey results and contextual observations with local stakeholders and community representatives involved in coastal governance processes. For peer debriefing, fellow researchers were engaged to obtain critical feedback on the choices of analysis and the interpretations that were emerging. At the same time, the audit trail was a collection of documented processes detailing how data were collected and analysed, as well as how decisions were made in the study. Assessing available documents of local policy, regional planning guidelines, and coastal management practices for the study areas significantly strengthened triangulation.

2.3 Data Analysis

Data were analysed using SmartPLS 4, based on the PLS-SEM approach. This method was selected due to its suitability for complex models involving multiple latent variables and indicators, as well as its robustness in handling non-normal data distributions. The analysis proceeded from the assessment of measurement model to structural model evaluation, to enable the examination of construct reliability, validity, and hypothesised relationships. Before model estimation, the dataset was screened to ensure completeness and consistency, thus allowing a reliable assessment of construct validity and reliability.

Initial data screening focused on verifying dataset completeness and integrity. This verification enabled the data evaluation to begin and, in turn, clarified specific missing values and data gaps. Cases with missing responses were handled using listwise deletion, as the proportion of incomplete data was below 5% and did not substantially reduce the effective sample size. Extreme values were identified using the ±3 standard deviation criterion and were excluded to minimise distortion of parameter estimates. These procedures were implemented to preserve data integrity and ensure analytical robustness before measurement and structural model evaluation. Once the dataset was confirmed to be in a good state for further analysis, the focus shifted to the evaluation of the measurement model, or the model of the indicators and constructs, to assess the strength of the relationships between the variables and the theoretical constructs. Validity assessment, in order words, convergent analysis, was based on the evaluation of outer loadings, AVE and reliability of variables. The variable indicators with low loadings were omitted, and further analysis showed that the remaining variables met the relevant benchmarks, with AVE values greater than 0.5, thereby validating the conclusions. The constructs' Composite Reliabilities were all greater than 0.9, thus confirming that the constructs were reliable and that they possessed internal reliability of sufficient magnitude. The assessment of cross-loadings showed that the constructs were indeed distinct and did not share loadings with any other constructs.

Once the strong measurement model was established, the inner model was examined to understand the causal relationships between the constructs. Among these relationships, community resilience had the highest explanatory power, as evidenced by an R^2 value above 0.9, indicating that a substantial proportion of the predictors accounted for its variance. Effect sizes (f^2) were calculated for each exogenous construct to determine the substantive contribution to the endogenous constructs, with values indicating small, medium, and large effects according to Cohen's criteria. Multicollinearity among predictors was assessed using the Variance Inflation Factor (VIF) and all recorded VIF values were below 5, indicating the absence of multicollinearity.

The significance of direct and indirect effects was tested using 5,000 bootstrapped samples. Indirect effects were assessed using standardised path coefficients (β), bias-corrected confidence intervals, and corresponding p-values, thereby enabling identification of the mediation type. All hypothesised paths were significant, and mediation analysis confirmed that collapsed capacity significantly mediated the relationship between engagement and community resilience. The study documented the positive Influence of community resilience as demonstrated through the significant interplay, whereas the effects of absence were noted through the respective interplay and cross-level coordination. The mediation analysis indicated that collapsed capacity was a significant mediator between engagement and resilience, suggesting that collapsed capacity formation is the primary mechanism linking governance activities to resilience outcomes. A summary of the data analysis workflow is presented in Table 2.

Table 2. Summary of the data analysis workflow using Partial Least Squares-Structural Equation Modelling

Analytical Stage	Focus of Analysis	Criteria Used / Outputs Evaluated	Key Outcomes
Data screening	Data quality & completeness	Missing values, Impact of extreme values, Assessment of data distribution	Datasets verified as appropriate for Smart-PLS Structural Equation Modelling
Measurement model	Indicator–construct relations	Outer loadings, AVE, indicator reliability	All constructs were valid after indicator refinement
Reliability testing	Internal consistency	Composite Reliability ($CR > 0.7$)	High reliability across all constructs
Discriminant validity	Construct distinctiveness	Cross-loadings comparison	No overlap among constructs
Structural model	Causal relationships	Path coefficients, t-statistics, p-values	Significant and non-significant paths identified
Model fit & predictive power	Variance explained	R^2 and effect sizes	High explanatory power for resilience ($R^2 > 0.9$)
Mediation analysis	Indirect effects	Bootstrapping 5,000 subsamples	Shared capacity (specified as a latent construct with validated indicators) confirmed as a key mediator
Interpretation	Integration with theory	CG-SES framework	Empirical insights aligned with theoretical expectations

Note: AVE—Average Variance Extracted; CG-SES—Collaborative Governance-Social Ecological Systems.

All in all, the PLS-SEM methodology provided an in-depth understanding of the measurement constructs and the other relations within the framework of CG-SES. The inclusion of f^2 effect sizes and VIF values in the analysis offered additional assurance regarding the robustness and explanatory contribution of the model constructs. The combination of strong validity, reliability, and R^2 values suggested that the model explained the relations among the constituent variables of collaborative governance to the extent that they could improve the resilience of coastal communities. The validity of those relations enhanced the reliability of the study and, as a result, its value in the theoretical and practical dimensions of coastal governance and adaptation.

3. Results and Discussion

3.1 Main Findings

In this study, data were adopted from 411 participants from 3 different coastal locations in West Sumatra: Padang City, Pesisir Selatan Regency, and the Mentawai Islands Regency. The sample size in this study was determined in advance to ensure sufficient statistical power to construct a complex PLS-SEM framework with multiple latent variables and over 40 indicators. Based on the studies of Hair et al. (2019) and Kline (2015), the sample size should be greater than 400 to ensure that the model could perform properly. There could also be a reduction in estimation errors, and the stability of the model was improved regarding mediation and interaction effects in the context of multivariate structures.

Using proportionate stratified random sampling, participants were selected to ensure the distribution matched the coastal population demographics across regions. As Padang City has the highest coastal population and is the most densely urbanised, it was the most surveyed area, followed by Pesisir Selatan Regency and the Mentawai Islands Regency, as shown in Table 3. Using Geographic Information System (GIS) tools and assistive relational validation, sampling designs confirmed that all sampled households were within a two-kilometre radius of the highest lunar tide mark. This sampling technique adheres to the spatial delineation boundaries set by Statistics Indonesia (Central Bureau of Statistics, 2023) and the guidelines of Integrated Coastal Zone Management (United Nations Environment Programme, 1995), to ensure that the participants indeed had the necessary socio-ecological characteristics of the coastal population.

The selected sample showed diversity in terms of gender and education levels, with 49.4% of respondents identifying as Men and 50.6% as Women, and education ranging from primary schooling to higher education. It also captured additional socio-demographic characteristics, such as age, occupation, and income, to provide a broader understanding of diversity within the coastal population. These thorough traits of participants ensured that the PLS-SEM model incorporated diverse perspectives and experiences, thereby enhancing the robustness of the analysis. While the full range of socioeconomic diversity could not be entirely captured, the sample provided a sufficiently representative basis for examining adaptive capacity, governance perception, and community resilience across coastal regions.

Lastly, with large enough, evenly sized, and appropriately distributed samples, alongside adequate representativeness in terms of spatial and demographic distributions, datasets that were parametrically and empirically sound for PLS-SEM analyses were created. This soundness provided robust empirical grounding for substantiating the preciseness of the relationships forged by collaborative governance systems, social and ecological skills, as well as community resilience. It was the respondents' distinct traits, particularly those from coastal regions, that most strongly bolstered the validity of the conclusions and their importance for adapting coastal regions.

Table 3. Distribution of respondents across coastal study areas

Region	Proportion of Coastal Population	Final Sample (*n* = 411)	Justifications
Padang City	50.6%	208	Largest coastal population; urban coastal pressures; high exposure to abrasion and tidal flooding
Pesisir Selatan Regency	40%	164	Rural-nagari governance system; strong adat institutions[1]; significant coastal fishery activities
The Mentawai Islands Regency	9.4%	39	Distinct island ecology; indigenous communities; geographic isolation
Total	100%	411	Ensures statistical power and proportional representation for Partial Least Squares-Structural Equation Modelling

Note: [1]Adat institutions embody the traditional and community-based systems of governance that oversee societal relationships and the stewardship of environmental assets within a local population.

The particular traits of these respondents established a solid empirical basis for subsequent analyses of the measurement and structural models, to ensure that they underpinned the study of governance systems and community resilience within a thoroughly representative coastal demography.

3.1.1 Convergent and discriminant validity

The determination of convergent and discriminant validity was based on a series of tests; constructs with less than satisfactory psychometric properties were diagnosed using these tests. The first step in convergent validity was to examine the indicator's outer loadings and the AVE for the various latent constructs. During this first step, there were 4 indicators, MA3, MB5, X1A2, and X2A3, which exhibited loadings with values lower than the required 0.5 criteria, therefore showing insufficient convergence toward the applicable latent variables. Following the PLS-SEM methodology, the decision was made to drop the indicated indicators to improve construct reliability and reduce conceptual ambiguity. Because the content overlapped with other items that could more closely articulate the constructs' core aspects, the withdrawn indicators were considered theoretically justifiable. The other indicators still offered sufficient coverage of the conceptual domain and, hence, maintained the substantive meaning of each latent variable. After piloting and expert review, the socio-ecological characteristics of Indonesian coastal communities were incorporated into the context, and the scales of measurement were modified from instruments in the governance and resilience literature. This was done before the main data collection.

Following the exclusion of low-loading indicators, the analyses focused on convergent validity. The results indicate that the remaining indicators for the five constructs (M, X1, X2, X3, and Y) had outer loadings ranging from 0.549 to 0.878, meeting the required threshold. In addition, all AVEs exceeded 0.5, suggesting that each latent variable explained more than half of the variance in its indicators. These findings confirm strong convergent validity in the overall model. The results of convergent validity, discriminant validity, and reliability are summarized in Table 4.

Table 4. Overview of convergent validity, discriminant validity, and reliability

Construct	Indicators (Retained/Removed)	Outer Loading (Final Model)	AVE	√AVE	Discriminant Validity	Composite Reliability
M Multilevel fit	Retained: MA1, MA2, MB4, MB6, MC7, MC8, MC9, MD10, MD11, MD12, ME13, ME14, ME15 Removed: MA3, MB5	0.605–0.823	0.504	0.710	√AVE > inter-construct correlations; cross-loading supports discriminant validity	0.929
X1 Collaborative governance	Retained: X1A1, X1A3, X1A4, X1B5, X1B6, X1B7, X1B8, X1C9, X1C10, X1C11, X1C12, X1D13, X1D14, X1D15, X1D16, X1E17, X1E18, X1E19, X1E20 Removed: X1A2	0.572–0.804	0.526	0.725	Valid (discriminant validity confirmed via Fornell–Larcker, cross-loadings, and Heterotrait–Monotrait ratio (HTMT); collinearity and effect size diagnostics assessed separately)	0.954
X2 Principled engagement	Retained: X2A1, X2A2, X2B4, X2B5, X2B6, X2C7, X2C8, X2C9, X2D10, X2D11, X2D12 Removed: X2A3	0.549–0.845	0.544	0.738	Valid based on all criteria	0.928
X3 Joint action	Retained: X3A1, X3A2, X3A3, X3B4, X3B5, X3B6, X3C7, X3C8, X3C9, X3D10, X3D11, X3D12	0.605–0.878	0.604	0.777	Strong discriminant validity (indicators' load highest on X3)	0.948
Y Community resilience	Retained: YA1, YA2, YA3, YB4, YB5, YB6, YC7, YC8, YC9, YD10, YD11, YD12, YE13, YE14, YE15	0.600–0.867	0.561	0.749	Valid (AVE > 0.5; Fornell–Larcker criterion met)	0.950

Note: AVE—Average Variance Extracted.

Discriminant validity was further evaluated by the Heterotrait–Monotrait ratio (HTMT). All HTMT values were below the recommended threshold of 0.85, indicating satisfactory discriminant validity. Two methods were used to assess discriminant validity in this study: the Fornell-Larcker criterion and cross-loadings analysis. Fornell and Larcker structured this analysis by stating that the square root of the AVE for each latent variable was greater than the correlation of that variable with all other variables, thereby concluding that each variable measured a separate, unique, and empirically distinct phenomenon in the study. This is also true of the cross-loading analysis, which illustrated that all indicators had higher loadings on the variables to which they were assigned than on any other latent variables, thereby confirming the absence of cross-loadings and verifying the internal structure of the measurement items. Overall, these findings demonstrated that the model met the criteria for discriminant validity and that the constructs measured different, not only theoretically but also empirically, dimensions of collaborative governance, social-ecological capacity, multilayer governance fit, and community resilience.

3.1.2 Structural model (inner model)

Once the measurement model had been verified, the next step was to assess the structural model, focusing on how the latent variables might Influence one another. This included examining the R^2 values for the endogenous variables, the strength of the paths, and the overall predictive capability of the model. Since the composite reliabilities for the constructs exceeded the required level of 0.7, the latent variables demonstrated substantial internal consistency and could be included in the structural model.

The high R^2 of the model suggested strong explanatory power. The endogenous variable Y in Table 4 had an R^2 value of 0.941, which means that the exogenous variables in the model explain 94.1% of its variance, and the other 5.9% is due to other variables not in the model. For the mediating variable M, the R^2 was 0.926, indicating that the model's relationships explain 92.6% of M's variance. Hair et al. (2019) stated that an R^2 value above 0.75 was good, and 0.925 was high; therefore, it was a good value. To rule out the possibility that the high explanatory values were due to a statistical anomaly, common method variance was assessed using both statistical and methodological approaches, and collinearity was assessed using VIF, which was within acceptable limits. Possible collinearity was checked using the $v = F$ method. Possible construct redundancy was also checked, and the constructs were confirmed to capture related but distinct dimensions. Consistent with the predictive nature of PLS-SEM, the predictive relevance of the model was evaluated using Q2, which showed that it had good predictive power, indicating that it could predict values not included in the model.

Consequently, the results provided evidence for both associative and explanatory relationships, rather than causal impacts, which spoke to the capacity of the modelling to collaboratively govern the resilience of coastal socio-ecological systems.

To determine the strength and direction of the anticipated relations, the bootstrapping method was used to derive *t*-statistics, which were then used to estimate the structural relations. The path coefficients for all relationships had *t*-statistics greater than 1.96, indicating that all relationships were statistically significant at the 5% level. This confirms that the structural model accounts for how exogenous variables Influence the mediator (M) and the endogenous variable (Y).

Figure 4 presents the PLS-SEM structural model, showing the magnitudes and directions of the relationships among the latent variables. It displays the relational configuration among the constructs, in support of the theory that the dimensions of collaborative governance and the social-ecological characteristics have significant predictors of multilayer governance fit (M) and, subsequently, community resilience (Y). This provides further evidence and highlights the interconnectedness of the system.

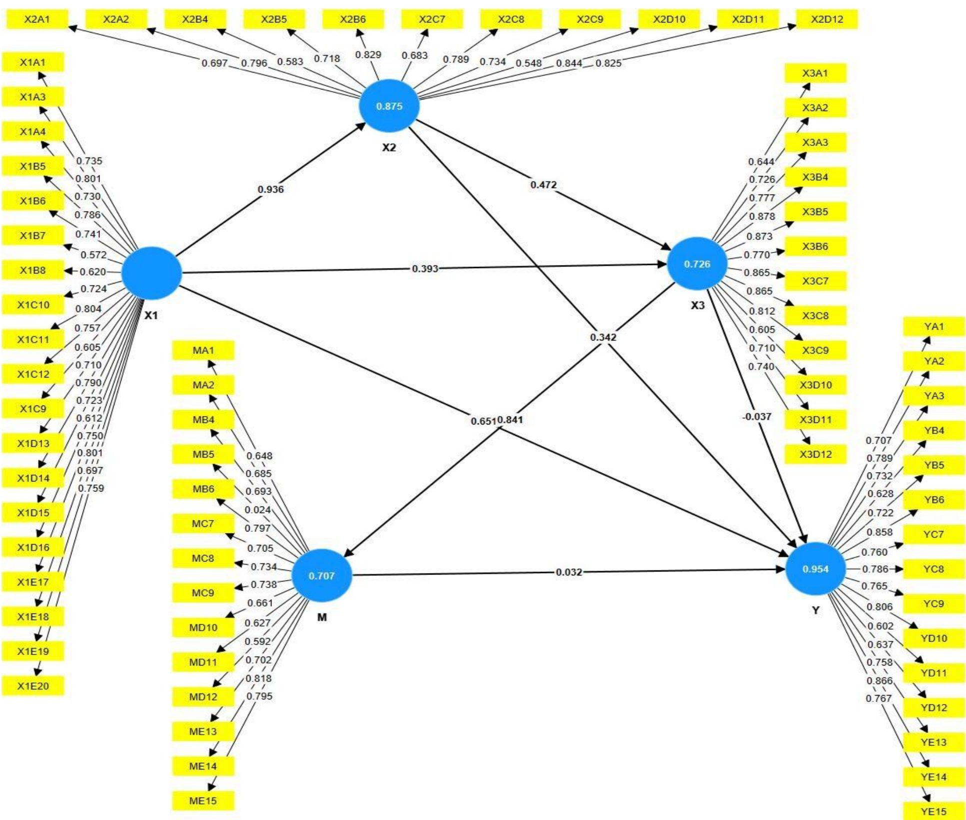

Figure 4. Final structural model with standardized loadings, path coefficients, and R^2

Source: Based on the Field Data.

In summary, the results from assessing convergent and discriminant validity collectively suggested that the measurement model had considerable psychometric reliability. Each construct satisfied the requirements for indicator reliability, internal consistency, and construct uniqueness, thereby increasing the credibility of the measurement model for assessing the structural model. In this study, the constructs were defined as follows: X1 = Collaborative Governance; X2 = Principled Engagement; M = Shared Capacity; and Y = Community Resilience. This clarification ensured that readers could directly interpret the relationships and pathways in the structural model without referring to figures or tables.

3.2 Discussion

The findings indicated a strong relationship between collaborative governance practices and community resilience within coastal social-ecological systems. Meaningful participation emerges as the most consistent and influential predictor, exerting strong direct effects on shared institutional capacity, collective action, and community resilience. In addition, shared capacity demonstrates significant direct effects on both collective action and resilience, thus confirming its central role in collaborative governance processes. By contrast, collective action does not function as a significant predictor of resilience, and multi-level fit neither moderates nor mediates the relationships examined. These results suggest that foundational collaborative efforts, particularly inclusive participation and strengthened institutional capacity, are more influential in shaping resilience outcomes than operational initiatives or vertical coordination alone (Putera et al., 2026). Overall, the findings are consistent with the proposed hypotheses, structural paths, and the results of the full structural model.

Although the sample size was sufficient to detect potential moderating and mediating effects, the absence of significant effects associated with multi-level fit appeared to be largely contextual. In the coastal governance setting of West Sumatra, vertical coordination was already relatively institutionalised, which might limit its additional explanatory power. As a result, formal alignment across governance levels does not necessarily translate into enhanced resilience when relational and capacity-based processes at the community level remain weak.

These findings corroborated and extended existing scholarship on collaborative governance. Previous studies emphasised that effective collaboration was underpinned by relational attributes such as trust, shared understanding, and inclusive engagement (Ansell & Gash, 2008; Bryson et al., 2015; Emerson & Nabatchi, 2015). The present study supports this perspective by demonstrating that meaningful engagement not only contributes directly to community resilience but also strengthens it by enhancing shared capacity. This emphasis on shared capacity is also consistent with the SES literature, which highlighted the importance of organisational resources, knowledge, and adaptive governance in strengthening system resilience (Berkes & Ross, 2013; Folke et al., 2010; Purnama et al., 2025). Conversely, the absence of substantial resilience outcomes associated with collective action may indicate that collaborative initiatives often suffer from limited institutional capacity, unclear role distribution, and insufficiently sustained stakeholder engagement.

Community-based activities such as planned clean-up initiatives, public meetings, or short-term volunteer mobilisation may provide social benefits, but they do not necessarily generate sustained adaptive capacity. Interpreting resilience solely in terms of the frequency or visibility of collective action risks oversimplified the complex dynamics of adaptation. Further investigation is therefore required to better understand the scope, intent, and institutional embeddedness of community self-organisation. One plausible explanation for the limited effect of collective action is the lack of stable provision of resources and weak institutional coupling between community initiatives and formal governmental planning frameworks, which constrain their long-term effectiveness.

Moreover, the absence of a significant mediating role for collective action suggests that resilience does not follow a simple linear pathway from engagement to capacity building, action, and outcomes. Instead, resilience appears more closely associated with fundamental governance values, including trust, representation, and inter-organisational collaboration. Similarly, the limited role of multi-level fit points to a persistent gap between community-driven initiatives and higher-level governance structures. This gap mirrors findings from national studies on coastal governance and reduction of disaster risk, which highlighted challenges in integrating local practices with broader policy frameworks.

From a theoretical perspective, this study contributes to the literature on collaborative governance and social–ecological systems by demonstrating that coastal resilience depends more on the quality of governance processes than on the visibility, frequency, or coordination of actions. From a practical standpoint, the findings imply that collaborative governance frameworks should prioritise the development of shared capacity through training, institutional integration, and strengthening of local governance before expecting measurable resilience outcomes. In policy terms, the limited effects of multi-level fit underscore the need for more meaningful coordination among village, district, and provincial governance actors, to ensure that community-initiated activities receive adequate structural support and long-term sustainability. The findings also hold methodological relevance, particularly for the development of resilience models using PLS-SEM.

Despite the frequent portrayal of collaboration as inherently transformative, the results suggest that such claims require greater nuance. In contexts characterised by weak institutional frameworks, collaborative efforts may be more symbolic than substantive. Caution is therefore warranted when designing engagement mechanisms, allocating resources, and defining stakeholders' roles, especially given the diversity of cultural norms, power relations, and governance histories across coastal regions. This study is subject to certain limitations, including reliance on self-reported survey data and a focus on three coastal areas, which may constrain the generalizability of the findings.

Nevertheless, the results provide a foundation for developing more concrete action agendas to strengthen collaborative governance for coastal resilience. Local governments, particularly at the city and district levels, should adopt more interactive governance models that facilitate multi-stakeholder dialogue and inclusive consultation. Strengthening community-based relational data systems, improving disaster literacy, and formally integrating indigenous knowledge into planning processes may further enhance collective capacity. In addition, joint action requires managerial improvements through more deliberate resource allocation, sustained institutional frameworks, and effective oversight mechanisms. Ultimately, achieving meaningful multi-level fit may be facilitated through integrated governance hubs that enable local, district, and provincial authorities to co-design, finance, and evaluate resilience initiatives collaboratively.

Overall, this study advanced understanding of collaborative governance in coastal social–ecological systems by demonstrating that the depth of participation and the distribution of shared institutional capacity were more decisive for network resilience than joint action or vertical alignment in isolation. These findings underscored the importance of strengthening foundational governance systems as a prerequisite for building resilience in the context of climate change.

3.3 Implications

This study has identified a variety of implications pointing to a more intricate structural change in the understanding and practice of climate governance in delicate coastal areas. The shift in the traditional model, from focusing on joint action and multi-level coordination as the linchpins of adaptive success to more pertinent forms of engagement and collective capacity as the core determinants of community resilience, has opened avenues for the establishment of novel pathways in climate governance. CG and SES theory benefit, to a considerable extent, from this adaptive change in climate governance towards a more relational, capacity and polycentrically-driven approach. These implications are summarised sequentially in Table 5, which distils the principal findings and is followed by a pertinent lexical discussion.

Table 5. Implications of research findings for the paradigm shifts in climate governance

Empirical Findings	Interpretation	Theoretical Implications	Policy/Practical Implications
Joint action does not significantly affect community resilience	Collaborative activities remain fragmented and lack institutional grounding	Resilience depends on relational capacity and institutional readiness, not activity volume	Adaptation policies must emphasize foundational processes (trust, coordination, shared norms) rather than merely producing outputs
Multi-level governance alignment is non-significant	Vertical structures remain procedural and administrative, not enabling	Multi-level governance must shift from hierarchy - functionally enabling architecture	National–provincial–local institutions must act as resource brokers, not regulators; planning cycles must be realigned
Meaningful engagement and shared capacity show strong direct effects	Communities respond more to inclusion, transparency, and shared responsibility	Supports CG-SES integration: resilience emerges from relational–institutional factors	Institutionalize participatory forums, co-production practices, and capacity audits
Indirect pathways are mostly non-significant	Collaborative procedures function as separate parts rather than as cohesive units	Adaptation governance suffers a lack of systemic coherence; blocks of collaboration are fractured	Enhance cross-organization networks; reconfigure adaptation governance as a systemic chain rather than as fragmented acts
Capacity mediates engagement - resilience (significant)	The only true mechanism which can transform engagement into resilience is capacity.	The role of capacity is pivotal in the CG-SES dynamics.	Investments in governance literacy, coordination abilities, and institutional capacity building should be long-term.

Note: CG-SES—Collaborative Governance-Social Ecological Systems.

This study explained some of the most basic changes regarding climate governance impacts in the most vulnerable coastal areas. Moving away from the "adaptive success" focus of other governance frameworks, which perceive joint action or multi-level coordination to be the core of the structure, this study concluded that active involvement and consolidated capacity were the most fundamental pillars of community resilience. The centre of gravity assumption of CG and SES frameworks was contradicted by these findings, leading to the need to move climate governance along the lines of relational, capacity-focused, and polycentric approaches. The results were consequence-oriented, and in this vision, Table 5 contains other summaries of results with narrative elaborations.

To summarise, these consequences represented a significant shift in the governing structures that enabled adaptation to climate change within coastal social-ecological systems. The main point was that these actors did not take interlinked actions; rather, the ecosystemic and relational conditions surrounding their actions were critical. The absence of an impact on resilience from joint action was contrary to most theories of collaborative governance, which focused on action as the most important element of collaboration. This is consistent with a developing body of critical literature on CG-SES that suggested the effectiveness of governance was a function of the underlying trust, mutual understanding, and role clarity, rather than the actions taken. Ultimately, action within capacity was transformative; alternatively, action outside capacity was merely schematic.

Finally, the remaining factors were related to the ineffective functioning of multi-layered governance structures. While many assumed that vertical coordination enhanced community resilience, this study revealed that managerial integration of institutions was a little more than a managerial and symbolic exercise, often disconnected from the realities of coastal communities. This should challenge the received wisdom in climate policy, especially in the Global South, that multi-layered governance arrangements were self-evidently more effective in promoting adaptive responses. The governance system had no downward accountability and no alignment with its planning cycles; it had not empowered local players to make a difference. It, therefore, became necessary to reframe multi-level governance in terms of a slack conceptualisation rather than as a system norm in which primary compliance and oversight were relieved of the system.

4. Conclusions

This study provided robust empirical evidence that the relational and institutional dimensions of collaborative governance, rather than integrated action or multi-level governance arrangements, were the primary determinants of coastal community resilience in West Sumatra. The findings demonstrated that meaningful engagement and shared institutional capacity exerted the strongest direct Influence on resilience outcomes. This confirms that adaptive capacity in coastal social-ecological systems is fundamentally grounded in trust-building, shared understanding, and sustained collaboration.

By contrast, integrated action and multi-level governance arrangements did not emerge as decisive determinants of resilience in this context. This suggests that limited relational resources or weak institutional embedding constrain the effectiveness of operational initiatives and vertical coordination. Accordingly, the findings reinforced the need to move beyond hierarchical, command and control governance toward relational, participatory, and capacity-driven governance models.

The study contributes to the advancement of collaborative governance and social-ecological systems (SES) theory by demonstrating the central role of institutional capacity and relational dynamics in shaping resilience outcomes. From a policy perspective, the findings underscore the importance of prioritising participatory approaches, strengthening institutional cohesion, and enhancing coordination across governance levels to address fragmentation in coastal management. Sustained investment in social and institutional capacity is therefore critical for effective climate adaptation.

Despite these contributions, this study is subject to several limitations. The cross-sectional design limits the ability to capture temporal dynamics, while reliance on self-reported data may introduce perceptual bias. In addition, the focus on three coastal regions may restrict the generalisability of the findings. Future research is therefore encouraged to adopt longitudinal approaches, integrate structural equation modelling with network analysis, and expand comparative studies across diverse coastal contexts.

Overall, this study highlights the significance of relational governance as a key mechanism for building coastal resilience and provides a structured and empirically grounded framework to support adaptive, inclusive, and effective climate governance in vulnerable coastal systems.

Author Contributions

Conceptualization, R., R.E.P., A.Z., and H.K.; methodology, R.E.P. and A.Z.; software, R.E.P.; validation, R.E.P. and A.Z.; formal analysis, R., A.Z., and H.K.; investigation, R., R.E.P., A.Z., and H.K.; resources, R.; data curation, R.E.P. and A.Z.; writing-original draft preparation, R., R.E.P., A.Z., and H.K.; writing-review and editing, R., R.E.P., A.Z., and H.K.; visualization, R.E.P. and A.Z.; supervision, R. and A.Z.; project administration, R.; funding acquisition, R. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data supporting our research results were included in the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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