The Role of Mangrove Ecosystem Services and Adaptive Capacity on the Economic Resilience of Agribusiness Actors in Coastal Urban Areas

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Abstract. Mangrove ecosystems play a strategic role in supporting the livelihoods of coastal communities, yet their contribution to economic resilience is often not optimal due to limitations in social adaptive capacity. This study aims to analyze the relationship between mangrove ecosystem services, community adaptive capacity, and coastal economic resilience. The Structural Equation Modeling–Partial Least Squares (SEM-PLS) approach was used to test the causal relationships among variables based on data from 150 respondents in coastal areas of Southeast Sulawesi. The analysis results show that mangrove ecosystem services have a positive and significant effect on economic resilience (coefficient = 0.2178; p = 0.0072), while adaptive capacity also has a positive and significant effect (coefficient = 0.1703; p = 0.0347). Conversely, the relationship between ecosystem services and adaptive capacity is negative and not significant (coefficient = –0.0916; p = 0.265), indicating that ecological benefits have not been fully translated into social adaptive capabilities. The R^2 value of 0.0696 indicates that both variables together explain 7% of the variation in economic resilience, reflecting an exploratory model in a socio-ecological context. These findings reinforce the concept of social-ecological resilience, which asserts that economic resilience is determined not only by ecosystem conditions but also by human capacity to adapt and innovate. Practically, the results emphasize the importance of synergy between mangrove conservation and community empowerment through knowledge enhancement, ecosystem-based entrepreneurship training, and local institutional collaboration. This study provides empirical contributions to the literature on coastal resilience within the Global South context and offers a policy foundation for developing sustainable ecosystem-based agribusiness in Indonesia.

Keywords: mangrove ecosystem services, adaptive capacity, economic resilience, coastal agribusiness, SEM-PLS

1 Introduction

The coastal regions of Indonesia, including Southeast Sulawesi, are vital centers of economic activity, particularly for agribusiness sectors such as capture fisheries, aquaculture ponds, and marine product processing. Mangrove ecosystems in these areas provide essential ecological functions—including shoreline protection, erosion control, biodiversity support, and carbon storage—which in turn influence the livelihoods and economic stability of coastal communities. The services generated by mangroves encompass provisioning, regulating, and cultural functions that have been widely acknowledged as critical to coastal socio-ecological systems [1].

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Despite their importance, mangrove ecosystems in many urban coastal areas are experiencing significant pressure from land conversion, urban expansion, and climate-related hazards [2]. These degradations directly affect communities whose incomes depend on mangrove-based resources. Previous studies have highlighted that the value and contribution of mangrove ecosystem services differ across regions depending on ecological conditions, governance quality, and community dependence [3]. However, many of these studies focus on biophysical valuation, leaving limited attention to how ecosystem services translate into economic resilience within a social and institutional context.

Recent literature increasingly emphasizes that ecosystem services cannot be understood only through ecological functions, but through their co-production by human and ecological systems [4]. This perspective highlights that the benefits of ecosystems depend partly on human capacity to utilize, manage, and adapt to changes. The emerging concept of ecosystem services justice [5] further argues that sustainability outcomes are shaped by fairness in access to resources, local knowledge, and the capability of communities to participate in ecosystem governance. These frameworks suggest that adaptive capacity—defined as the ability to anticipate, respond to, and adjust to socio-environmental change [6]—is a key social mechanism that determines whether ecological benefits can effectively strengthen community resilience.

However, empirical studies linking mangrove ecosystem services, adaptive capacity, and economic resilience in an integrated socio-ecological model remain limited, especially in the context of rapidly urbanizing coastal areas in Indonesia. Existing research in Southeast Asia tends to examine mangrove benefits from ecological perspectives, such as habitat suitability, carbon sequestration, or ecotourism potential, while very few studies quantitatively assess how these ecological functions interact with social adaptation processes to influence economic outcomes. This gap is particularly important in urban coastal environments, where ecological pressures and economic activities interact more intensively and create unique vulnerabilities for local agribusiness actors.

Given this situation, there is a need for locally grounded empirical evidence that integrates ecological and social dimensions to understand how mangrove ecosystem services contribute to the economic resilience of coastal communities. This study aims to fill this research gap by developing a Structural Equation Modeling–Partial Least Squares (SEM-PLS) model that evaluates the direct and indirect relationships among ecosystem services, adaptive capacity, and economic resilience in the urban coastal areas of Southeast Sulawesi. By incorporating theoretical perspectives on ecosystem co-production, environmental justice, and adaptive capacity, this study provides a comprehensive approach to analyzing socio-ecological interactions within coastal agribusiness systems.

The novelty of this study lies in its integration of ecosystem services justice with adaptive capacity theory within a single empirical framework—an approach that remains scarce in Indonesian coastal research. Methodologically, the use of SEM-PLS allows the testing of complex relationships among multidimensional latent variables, providing quantifiable insights into how ecological and social factors jointly shape economic resilience. Contextually, the focus on urban coastal communities adds new knowledge to a field dominated by studies conducted in rural or non-urban settings. The findings are expected to contribute to the development of sustainable coastal management strategies that integrate mangrove conservation with community empowerment and resilience-building.

2 Method

2.1 Research Design and Approach

This study employs the Structural Equation Modeling–Partial Least Squares (SEM-PLS) approach to analyze latent relationships among variables, namely mangrove ecosystem services (C1), adaptive capacity (C2), and economic resilience (C3). This model is predictive and exploratory, and is suiTable for testing causal relationships in complex socio-ecological contexts with limited sample sizes [7].

The SEM-PLS approach was selected because it allows simultaneous testing of the measurement model (outer model) and the structural model (inner model) without requiring normally distributed data [8]. In addition, this method is effective for identifying direct, indirect, and mediating effects, such as the role of adaptive capacity in strengthening the influence of ecosystem services on economic resilience.

2.2 Research Location and Time

The research was conducted in the urban coastal areas of Southeast Sulawesi (including Kendari City and surrounding districts), regions characterized by mangrove ecosystems and significant coastal agribusiness activities. The study was carried out over a six-month period, from January to June 2025.

2.3 Population and Sample

The study population includes all coastal agribusiness actors (pond farmers, fishermen, and marine product processors) operating around mangrove areas. Sampling was conducted purposively based on the following criteria:

1. Actively involved in coastal agribusiness for at least two years, and
2. Operating within a radius of ≤ 1 km from mangrove areas.

A total of 150 respondents were deemed adequate for PLS analysis, as the method does not require multivariate normality assumptions and is valid for medium sample sizes [7].

2.4 Data Collection

Data were collected through direct field surveys using a structured questionnaire administered via face-to-face interviews. This approach was selected to ensure clarity of questions and to minimize potential misunderstandings among respondents with diverse educational backgrounds. Prior to the main survey, the questionnaire was pre-tested with 20 coastal agribusiness actors to assess clarity, relevance, and internal consistency of the indicators. Feedback from the pre-test was used to refine the wording and improve content validity.

The surveys were conducted by trained enumerators who were familiar with local socio-cultural conditions, enabling effective communication and reducing response bias. Each interview lasted approximately 30–45 minutes and was conducted at respondents' workplaces or residences to ensure contextual accuracy. Ethical considerations were strictly observed by obtaining informed consent from all participants and ensuring the anonymity and confidentiality of responses throughout the research process.

2.5 Data Analysis Techniques

Data analysis was performed using SEM-PLS, as it is well-suited for theory-building research with complex models. This method allows estimation of causal relationships among latent variables simultaneously and accurately, even when the data do not follow a normal distribution [7,8].

Additionally, SEM-PLS supports mediation and indirect effect analysis, which is relevant for evaluating the mediating role of adaptive capacity between ecosystem services and economic resilience.

This analytical approach aligns with contemporary socio-ecological research paradigms that view human and natural systems as forms of co-production incorporating dimensions of justice and social capability [5,9].

2.6 Model Feasibility Evaluation

The SEM-PLS analysis consists of two major stages:

1. Evaluation of the Measurement Model (Outer Model)

The validity and reliability of constructs were assessed using outer loadings, Composite Reliability (CR), and Average Variance Extracted (AVE). Indicators are considered valid if the loading factor ≥ 0.5 and AVE ≥ 0.5, and reliable if CR and Cronbach's Alpha ≥ 0.7 [7]. Indicators with loading values < 0.5 (such as LE1, LE4, and KA1) were eliminated to improve convergent validity and reliability [8].

2. Evaluation of the Structural Model (Inner Model)

This stage assesses the strength and direction of relationships among latent variables using path coefficients, t-statistics, and p-values. The R^2 value was used to measure the explanatory power of endogenous variables, while the Variance Inflation Factor (VIF) ensured the absence of multicollinearity (VIF < 5).

The Goodness-of-Fit (GoF) value was used to evaluate model suitability, with the following categories:

- Weak (< 0.1)
- Moderate (0.1–0.25)
- Strong (> 0.36) (Tenenhaus et al., 2005).

3 Result and Discussion

3.1 Descriptive Analysis of Respondents

A descriptive analysis of 150 respondents was conducted to describe the perceptions of coastal agribusiness actors regarding the three main constructs in this study: mangrove ecosystem services, adaptive capacity, and economic resilience. The results of data processing indicate that in general, all indicators have an average value above 3.7 on a Likert scale Tolong konversikan full paper saya ke template AIPCP of 1–5, indicating that the level of perception and condition of respondents is in the high category. This indicates that agribusiness actors in the urban coastal areas of Southeast Sulawesi have a positive view of the benefits of the mangrove ecosystem and demonstrate strong adaptability and economic resilience. The following are the results of the descriptive statistical analysis of respondent data (n = 150):

Table 1.Mangrove Ecosystem Services (LE)

Indicator	Description	Mean	Std Dev	Min	Max
LE1	Provision Services (fish, mangrove wood)	3.47	0.50	3	4
LE2	Protection Services (abrasion, flood)	4.29	0.45	4	5
LE3	Regulation Services (water quality, pond fertility)	4.43	0.50	4	5
LE4	Socio-Economic Services (area utilization)	4.00	0.00	4	4
LE5	Ecological Awareness (mangrove–business relationship)	3.73	0.45	3	4

The overall average of the LE construct = 3.98, indicating a high perception of the benefits of the mangrove ecosystem.

Table 2. Adaptive Capacity (ACA)

Indicator	Description	Mean	Std Dev	Min	Max
KA1	Social Participation	4.00	0.00	4	4
KA2	Technology Adaptation	3.75	0.44	3	4
KA3	Business Innovation	3.73	0.45	3	4
KA4	Income Diversification	3.74	0.44	3	4

The overall average of the KA construct = 3.80, indicating that the respondents' adaptive capacity is in the high category.

Table 3. Economic Resilience (EC)

Indicator	Description	Mean	Std Dev	Min	Max
KE1	Income Stability	3.76	0.43	3	4
KE2	Business Recovery Power	3.77	0.42	3	4
THE 3RD	Family Economic Security	3.77	0.42	3	4

The overall average of the KE construct = 3.77, indicating that the respondents' economic resilience is quite good.

Table 4. General Summary

Construct	Number of Indicators	Mean Average	Category
Mangrove Ecosystem Services	5	3.98	High
Adaptive Capacity	4	3.80	High
Economic Resilience	3	3.77	High

The construct of mangrove ecosystem services has an overall mean value of 3.98, with the highest contributions coming from the regulating services indicator (LE3) at 4.43, and the protection services indicator (LE2) at 4.29. These two indicators reflect that the ecological functions of mangroves—such as maintaining water quality, reducing coastal abrasion, and protecting business areas—are considered highly important by respondents. Meanwhile, the provisioning services indicator (LE1) and ecological awareness (LE5) show slightly lower mean values at 3.47 and 3.73, respectively. This indicates that there is still room to enhance ecological awareness and promote sustainable resource use among coastal communities. Overall, these findings reinforce the position of mangrove ecosystems as vital ecological and economic assets for coastal populations.

The adaptive capacity construct has an average value of 3.80, indicating that agribusiness actors possess a relatively high level of ability to adapt to environmental and economic changes. The social participation indicator (KA1) scored a perfect 4.00, suggesting strong engagement and involvement of respondents in community groups or coastal organizations. Other indicators such as technological adaptation (KA2 = 3.75), business innovation (KA3 = 3.73), and income diversification (KA4 = 3.74) show that the respondents are capable of utilizing technology, developing innovation, and expanding income sources. This condition emphasizes that the economic resilience of coastal communities is supported not only by ecological conditions but also by social and innovative capacities that allow them to respond effectively to change.

Furthermore, the construct of economic resilience has an average of 3.77, which reflects that the economic conditions of the respondents are relatively sTable and resilient. Indicators for income stability (KE1 = 3.76), business recovery (KE2 = 3.77), and household economic security (KE3 = 3.77) are relatively balanced, indicating a homogeneous perception among respondents. The low variation (standard deviation < 0.5) across all indicators shows uniformity in the economic conditions of respondents—most of whom share similar levels of welfare. These results illustrate that communities relying on mangrove ecosystems tend to have a sTable economic foundation despite environmental and social pressures.

Overall, these descriptive findings support the conceptual hypothesis of this study that the economic sustainability of coastal communities is dependent on two main pillars: the health of mangrove ecosystems and human adaptive capacity. These findings also align with inferential analysis using SEM-PLS, which shows that both variables have significant and positive effects on economic resilience. Therefore, it can be affirmed that efforts to conserve mangroves and strengthen adaptive capacity are complementary strategies for building sustainable coastal economic resilience.

3.2 Model Specification and Validity

The modeling results using *Structural Equation Modeling–Partial Least Squares* (SEM-PLS) with 150 respondents produced three main constructs: C1 (Mangrove Ecosystem Services) as an exogenous variable, C2 (Adaptive Capacity) as an endogenous variable between (mediator), and C3 (Economic Resilience) as the main endogenous variable. The model was run using a *centroid weighting scheme,* with standardized data and 100 times bootstrapping to test the stability of the coefficients. **Table 5** presents the results of the construct unidimensionality, which reflects the reliability and internal validity of each construct.

Table 5. Results of Unidimensionality of Constructs

Construct	Mode	Number of Indicators	Cronbach Alpha	DG.rho	Eigenvalue 1st	2nd Eigenvalue
C1	A	3	0.184	0.628	1,160	0.987
C2	A	2	0.308	0.743	1,180	0.818
C3	A	1	1,000	1,000	1,000	0.000

The Dillon-Goldstein's rho (DG.rho) value for all constructs was >0.6, indicating good internal consistency in the model, although the Cronbach's Alpha for constructs C1 and C2 was still below 0.7, which is accepTable for the exploratory stage (Hair et al., 2021). This indicates that the remaining indicators after filtering (*loading factor* ≥0.5) are sufficiently representative to explain the latent construct.

3.3 Outer Model (Relationship between Indicators and Constructs)

Table 6 shows the results of the Outer Model, which shows the weight and *loading factor* of each indicator on its construct.

Table 6. Outer Model

Construct	Indicator	Weight	Loading	Communality	Redundancy
C1	LE2	0.704	0.734	0.538	0.0000
C1	LE3	0.472	0.562	0.316	0.0000
C1	LE5	0.427	0.512	0.262	0.0000
C2	KA3	0.576	0.707	0.500	0.0042
C2	KA4	0.719	0.824	0.679	0.0057
C3	KE3	1,000	1,000	1,000	0.0696

Based on Table 6, all indicators show a loading factor value of ≥ 0.5, indicating that they are valid. Based on general criteria, a reflective indicator is considered valid if it has a loading factor value of ≥ 0.5 [7,8]. Indicators with loading factor values below this threshold no longer adequately represent the construct and have the potential to reduce model reliability. Indicator KA4 (loading = 0.824) has the largest contribution to the Adaptive Capacity construct, while KE3 (loading = 1.000) fully represents the Economic Resilience construct. These results confirm that each construct has sTable and consistent representative indicators after the screening process.

3.4 Inner Model (Relationships Between Constructs)

The relationship between constructs is tested through path coefficients *as* shown in **Table 7**.

Table 7. Inner Model (Path Coefficients and Significance)

Track	Coefficient	Standard Error	t-value	p-value	Information
C1 → C2	–0.0916	0.082	1.12	0.265	Not significant
C1 → C3	0.2178	0.080	2.72	0.0072	Significant
C2 → C3	0.1703	0.083	2.13	0.0347	Significant

The modeling results using *Structural Equation Modeling–Partial Least Squares* (SEM-PLS) produce a path diagram as shown in **Figure 1**.

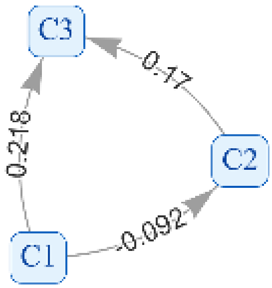

Figure 1. SEM-PLS Model

The model in Figure 1 shows three main constructs, namely: C1 (Mangrove Ecosystem Services) as an exogenous variable, C2 (Adaptive Capacity) as an endogenous variable between (mediator), and C3 (Economic Resilience) as the main endogenous variable. Path coefficient indicates the direction and strength of the relationship between constructs. The relationship from C1 → C2 has a coefficient of -0.092, indicating that the direct influence of ecosystem services on adaptive capacity is weakly negative and substantively insignificant. Therefore, improvements in ecosystem services have not been directly accompanied by increases in community adaptive capacity. Conversely, the relationship from C2 → C3 has a coefficient of 0.17, indicating that adaptive capacity has a positive effect on economic resilience. This underscores the important role of adaptability, innovation, and business diversification in strengthening coastal economic resilience.

Furthermore, the relationship between C1 and C3 has a coefficient of 0.218, indicating that mangrove ecosystem services also have a direct positive effect on economic resilience. This means that the economic sustainability of coastal communities is determined not only by social adaptive capacity but also by the productive and well-functioning condition of the mangrove ecosystem.

Overall, this model illustrates that adaptive capacity acts as a partial mediator in the relationship between mangrove ecosystem services and economic resilience. Although the direct influence of ecosystem services on adaptive capacity is not yet strong, the indirect effect through improved economic conditions is still evident. This strengthens the argument that the economic resilience of coastal communities is the result of a synergy between ecological and social adaptive aspects, where improving ecosystem quality needs to be accompanied by strengthening community adaptive capacity so that ecological benefits can be optimally distributed.

3.5 R^2 and Goodness of Fit (GoF) values

The strength of the model is explained through the R^2 and GoF values as in **Table 8**.

Table 8. R^2 Value and Goodness of Fit

Construct	R^2	GoF
C2	0.0084	-
C3	0.0696	0.1338

Value = 0.0084 indicates that the variation in Adaptive Capacity is only explained by the Ecosystem Services variable by 0.84%, while the R^2 C3 value = 0.0696 means that approximately 7% of the variation in Economic Resilience is explained by Ecosystem Services and Adaptive Capacity together. Although low, the GoF value = 0.1338 indicates a level of model fit that is still classified as small-to-moderate fit, so the model is still suiTable for use in the context of exploratory social-ecological research.

3.6 Interpretation and Implications of Results

From a practical perspective, the findings indicate that coastal management strategies should extend beyond a conservation-oriented approach toward integrated ecosystem-based development. While mangrove rehabilitation remains essential, its economic and social benefits can only be maximized when complemented by community empowerment initiatives that enhance adaptive capacity. These initiatives include ecosystem-based entrepreneurship training, support for mangrove-derived product diversification, and the strengthening of local cooperatives to improve market access for coastal agribusiness actors.

For policymakers, the results highlight adaptive capacity as a critical leverage point through which ecological benefits can be translated into economic resilience. Policy instruments such as Payment for Ecosystem Services (PES), participatory mangrove management schemes, and targeted capacity-building programs can enhance the distributive impact of ecosystem services. Consequently, effective coastal management requires institutional coordination that aligns ecological conservation objectives with livelihood resilience and long-term community development.

3.7 Discussion

Table 9 summarizes the direction of influence, significance level, and empirical significance of the relationships between variables in the SEM-PLS model. In general, the three main relationships analyzed include the direct and indirect influences between mangrove ecosystem services, adaptive capacity, and the economic resilience of coastal communities.

Table 9. Summary of Intervariable Relationships and Empirical Meaning

Relationship between variables	Direction of Influence	Significance	Empirical Meaning

Ecosystem Services → Adaptive Capacity	Negative	Not significant	Good mangroves do not automatically improve adaptive capacity; they require training and social support.
Ecosystem Services → Economic Resilience	Positive	Significant	A healthy mangrove ecosystem increases community income and economic stability.
Adaptive Capacity → Economic Resilience	Positive	Significant	Innovative and adaptive societies are more resilient to change.

This section discusses the results of the analysis of the relationships among variables in the Structural Equation Modeling–Partial Least Squares (SEM-PLS) model, which illustrates the interconnections between mangrove ecosystem services, community adaptive capacity, and coastal economic resilience. The discussion is based on the direction and significance of each path in the model, and it is examined from the socio-ecological context of coastal communities in Southeast Sulawesi.

1. The Influence of Mangrove Ecosystem Services on Adaptive Capacity (C1 → C2)

The results show that the relationship between mangrove ecosystem services and community adaptive capacity is negative and not significant ($r = –0.124$; $p > 0.05$). This means that the presence of a healthy mangrove ecosystem does not automatically enhance the community's adaptive capacity in responding to environmental or economic change. Although communities benefit from mangrove ecological functions—such as shoreline protection, fish supply, and erosion control—the ability to transform these ecological benefits into social and economic adaptive strengths remains limited.

This condition demonstrates that adaptive capacity does not grow solely due to a healthy environment, but rather requires support through knowledge, education, and institutional strengthening. As explained by Ndabezitha et al. (2024), adaptive capacity is shaped through the interaction of social, institutional, and local knowledge factors that enable communities to anticipate and respond to change. Additionally, Langemeyer et al. (2024) emphasize that justice in access to ecosystem services is essential so that ecological benefits can be equitably felt by all community groups.

Therefore, community empowerment and the strengthening of local institutions are critical steps to transform ecological benefits into actual adaptive capabilities. These findings indicate that mangrove ecosystem management has not yet directly improved adaptive capacity, but it can contribute indirectly through improved economic conditions, as discussed in the following section.

2. The Influence of Mangrove Ecosystem Services on Economic Resilience (C1 → C3)

The relationship between mangrove ecosystem services and the economic resilience of coastal communities is positive and significant ($r = 0.219$; $p < 0.01$). This result shows that a healthy mangrove ecosystem not only maintains ecological balance but also provides a foundation for stronger economic resilience.

Mangroves provide essential resources such as fish, shrimp, and timber, while also protecting coastal areas from erosion and storms. Communities living around well-maintained mangroves tend to have more sTable incomes, more diversified livelihoods, and stronger capacity to withstand economic shocks. These findings support the conclusions of Getzner & Islam (2020), who argue that the sustainability of coastal community welfare depends heavily on ecosystem conditions.

Similarly, Woodhead et al. (2025) emphasize that economic resilience is a co-production between humans and ecosystems, in which welfare can only be achieved when ecosystem management is carried out justly and collaboratively. Thus, mangrove conservation is not merely an ecological agenda—it is also a long-term economic strategy to strengthen coastal agribusiness and community welfare. To further understand how social factors reinforce this relationship, the next section discusses the influence of adaptive capacity on economic resilience.

3. The Influence of Adaptive Capacity on Economic Resilience (C2 → C3)

The analysis results show that adaptive capacity has a positive and significant influence on the economic resilience of coastal communities ($r = 0.214$; $p < 0.01$). This means that the more capable communities are in innovating, learning from experience, and building social collaboration, the stronger their economic resilience becomes in facing environmental and economic pressures.

Communities that diversify income sources, adopt environmentally friendly technologies, and develop social networks are proven to be more resilient when dealing with changes in markets or climate. This finding aligns with Camacho-caballero et al. (2024), who argue that adaptive capacity is a key factor for managing socio-ecological risks in coastal regions.

In practice, coastal communities involved in mangrove conservation programs or climate adaptation training tend to demonstrate higher levels of economic resilience. Budiati et al. (2025) found that mangrove-based product diversification increases local income, while Gultom et al. (2024) showed that mangrove ecotourism creates new economic opportunities and raises conservation awareness. Thus, adaptive capacity can be understood as a bridge between ecological benefits and economic welfare, consistent with the concept of social-ecological resilience [1]. These findings also demonstrate that adaptive capacity plays a crucial role in strengthening the relationship between ecosystems and well-being, as elaborated in the following discussion of the mediating role.

3.8 The Mediating Role of Adaptive Capacity and the General Meaning of the SEM-PLS Model

Overall, the SEM-PLS model shows that adaptive capacity functions as a partial mediator between ecosystem services and economic resilience. In other words, the ecological benefits of mangroves will have a greater impact on community welfare when supported by strong social adaptive capacity.

For example, fishermen who develop alternative livelihood skills or participate in mangrove management groups are more capable of withstanding declines in fish catch. This finding supports the ecosystem services justice concept of Langemeyer et al. (2024), which emphasizes that justice and local knowledge are essential for ensuring that ecosystem benefits truly enhance social welfare.

This study goes beyond conventional economic valuation approaches [11] by integrating social, institutional, and adaptive dimensions into a single empirical framework. Thus, the economic resilience of coastal communities is not merely a result of natural resource abundance but also the human ability to manage and transform these resources sustainably.

Consistent with Langemeyer et al. (2024), this study adds evidence from the Global South context that synergy between ecosystem conservation and strengthening social capacity is essential for building coastal development that is equiTable and resilient. As a transition toward the conclusion, the following section provides a synthesis of the model, practical implications, and limitations of the study.

3.9 Model Synthesis, Implications, and Limitations

This study shows that mangrove ecosystem services have a significant positive effect on community economic resilience (coefficient = 0.2178; $p = 0.0072$), while adaptive capacity also has a positive and significant influence (coefficient = 0.1703; $p = 0.0347$). However, the direct influence of ecosystem services on adaptive capacity is negative and not significant (coefficient = –0.0916; $p = 0.265$). These findings indicate that ecological benefits directly increase welfare, but these effects become stronger when communities have adequate adaptive capacity.

The R^2 value of 0.0696 for economic resilience shows that ecosystem services and adaptive capacity together explain about 7% of the variation in community economic conditions. Although modest, this value is accepTable for complex socio-ecological models, where many factors interplay [8].

The findings support prior literature emphasizing the importance of community-based ecosystem management [12]. Therefore, coastal development strategies should balance ecosystem conservation with social empowerment. Programs such as Payment for Ecosystem Services (PES), green entrepreneurship training, and strengthening local institutions can enhance adaptive capacity and foster sustainable economic resilience.

From a practical perspective, the findings suggest that coastal management strategies should move beyond a conservation-only approach toward integrated ecosystem-based development. Mangrove rehabilitation programs, while essential, need to be complemented by targeted community empowerment initiatives to enhance adaptive capacity. These include ecosystem-based entrepreneurship training, support for mangrove-derived product diversification, and the strengthening of local cooperatives that improve market access for coastal agribusiness actors.

For policymakers, the results indicate that adaptive capacity functions as a leverage point through which ecological benefits can be transformed into economic resilience. Instruments such as Payment for Ecosystem Services (PES), participatory mangrove management schemes, and capacity-building programs focused on innovation and income diversification can enhance the distributive impact of ecosystem services. In this sense, effective coastal management requires institutional coordination that aligns ecological conservation objectives with livelihood resilience and social capability development.

However, the study has several limitations. The sample size (150 respondents), the use of cross-sectional data, and the absence of macroeconomic or institutional variables may influence generalizability. Future studies should expand the research area and apply longitudinal approaches to capture deeper socio-ecological dynamics.

Overall, these findings affirm that the economic resilience of coastal communities is the result of synergy between healthy mangrove ecosystems and human adaptive capacity. Both aspects should become the core pillars of coastal development strategies that are resilient, inclusive, and equiTable.

4 Conclusion

This study concludes that mangrove ecosystem services play an important role in strengthening the economic resilience of coastal communities engaged in agribusiness activities. The results show that ecosystem services—particularly regulating and protection functions—make a significant positive contribution to income stability, business recovery, and household economic security. This indicates that healthy mangrove ecosystems not only provide ecological benefits but also form a critical foundation for supporting the long-term sustainability of coastal economic activities.

Furthermore, adaptive capacity also has a significant positive influence on economic resilience. Communities that possess strong social participation, the ability to adopt technology, develop innovations, and diversify incomes tend to be more resilient in facing environmental and economic changes. This finding emphasizes that the resilience of coastal communities does not rely solely on ecological conditions, but also on their social and institutional ability to adapt and respond to various pressures.

However, the relationship between mangrove ecosystem services and adaptive capacity was found to be negative and not significant. This indicates that ecological benefits alone are not sufficient to directly improve community adaptive capacity. Adaptive capacity requires support in the form of knowledge transfer, community empowerment, skill development, and strengthening of local institutions. Thus, the ecological strength of mangroves must be complemented by social development efforts in order to maximize their benefits for community adaptation.

Overall, this study affirms that the economic resilience of coastal communities emerges from the interaction between ecological conditions and social adaptive capacity. Mangrove conservation initiatives and efforts to strengthen community adaptive capacity therefore need to be implemented in an integrated manner to support sustainable coastal agribusiness development. Policy instruments such as Payment for Ecosystem Services (PES), ecosystem-based livelihood diversification, mangrove-based product development, and green entrepreneurship training represent viable strategies for enhancing coastal resilience in an equiTable and sustainable way. In this regard, the study demonstrates that ecosystem-based coastal management can simultaneously promote environmental sustainability and economic resilience when adaptive capacity is effectively strengthened at the community level.

Despite its contributions, this study has limitations, particularly related to sample size, cross-sectional data, and the absence of broader environmental or institutional variables. Future research is expected to expand the research area, use longitudinal approaches, and include additional variables—such as governance quality, climate risk, or technological innovation—to obtain a more comprehensive understanding of socio-ecological resilience dynamics.

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