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Climate Forecast Use, Livelihood Diversification, and Social Capital as Drivers of Livelihood Recovery Capacity among Small-Scale Fishers in Pelabuhan Ratu, Indonesia

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ABSTRACT

Climate variability, environmental uncertainty, and socioeconomic vulnerability pose significant challenges to the sustainability of small-scale fishing livelihoods, particularly in coastal communities that depend heavily on marine resources. This study aims to examine the relationships between climate forecast utilization, livelihood diversification, social capital, and livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. A quantitative approach with an explanatory research design was employed, involving 120 respondents selected through purposive sampling. Data were collected using structured questionnaires with a five-point Likert scale and analyzed using SPSS version 25 through validity and reliability testing, classical assumption tests, and multiple linear regression analysis. The findings reveal that climate forecast utilization, livelihood diversification, and social capital are positively and significantly associated with livelihood resilience. Among these factors, social capital demonstrates the strongest relative association, highlighting the importance of community networks, interpersonal trust, and collective support in strengthening fishermen's adaptive capacities. The results further indicate that access to climate information, diversification of household income sources, and effective social relationships collectively contribute to explaining livelihood resilience. These findings emphasize the importance of integrating accessible climate information services, alternative livelihood development, and community-based institutional support into sustainable coastal livelihood strategies. The study contributes empirical evidence to the understanding of livelihood resilience and provides practical insights for strengthening the adaptive capacity of small-scale fishing communities facing environmental and socioeconomic uncertainties.

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INTRODUCTION

Small-scale fisheries play a critical role in global food security, employment, and socioeconomic development, particularly in coastal communities whose livelihoods depend heavily on marine resources. According to the Food and Agriculture Organization of the United Nations (FAO) (*Illuminating Hidden Harvests: The Contributions of Small-Scale Fisheries to Sustainable*

Development, 2023; *The State of World Fisheries and Aquaculture 2024: Blue Transformation in Action*, 2024), small-scale fisheries account for approximately 40% of global fish catches, support around 90% of the capture fisheries workforce, and contribute to the livelihoods of approximately 500 million people worldwide. Despite their substantial contribution, small-scale fishing households remain disproportionately exposed to environmental degradation, climatic variability, economic instability, and limited access to productive resources. Climate-induced changes in sea surface temperatures, rainfall patterns, ocean currents, and extreme weather conditions increasingly disrupt fishing activities, resource availability, and household income security. The Intergovernmental Panel on Climate Change (IPCC) (Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022) emphasizes that climate-related transformations in marine ecosystems pose considerable socioeconomic challenges for fisheries-dependent communities, particularly those with limited adaptive resources. These pressures underscore the importance of livelihood resilience, which encompasses the capacity of households to anticipate disturbances, maintain essential economic functions, adapt livelihood strategies, and recover from environmental and socioeconomic shocks. Understanding the factors associated with such resilience has therefore become increasingly important for advancing sustainable coastal development and climate adaptation policies.

Indonesia represents a particularly relevant context for investigating livelihood resilience because of its extensive coastal ecosystems, substantial fisheries resources, and the economic dependence of numerous coastal households on small-scale fishing activities. However, Indonesian fishing communities frequently encounter seasonal income fluctuations, limited financial resources, uncertain fishing opportunities, and unequal access to institutional assistance. Handayati et al. (Handayati et al., 2025), examining small-scale fisheries in South Malang, demonstrate that climate variability and household livelihood strategies are closely connected to fishermen's socioeconomic vulnerability and adaptive capacity. These challenges are also evident in Pelabuhan Ratu, Sukabumi Regency, West Java, where fishing productivity is influenced by seasonal oceanographic fluctuations and changing marine environmental conditions. Pratama et al. (Pratama et al., 2022) identify relationships between pelagic fishing patterns, sea surface temperature, and chlorophyll-a concentrations in Palabuhanratu waters. Similarly, Mulyasari et al. (Mulyasari et al., 2023) report that small-scale fishers on the northern coast of Bengkulu, Indonesia, perceive changes in local climate and respond to them mainly by adjusting their fishing timing. These conditions indicate that livelihood sustainability in Pelabuhan Ratu depends not only on marine resource availability but also on fishermen's capacity to access information, diversify economic opportunities, and mobilize social support.

Climate forecast utilization, livelihood diversification, and social capital represent three potentially complementary mechanisms for strengthening livelihood resilience among small-scale fishing households. Climate forecast utilization enables fishermen to anticipate unfavorable marine conditions, adjust fishing schedules, manage operational risks, and improve livelihood decision-making. Nevertheless, its effectiveness depends on the accessibility, reliability, comprehensibility, and practical application of meteorological information. Mulyasari et al. (Mulyasari et al., 2023) show that fishers actively seek climate information to decide when to go to sea and to reduce their risk, underscoring the value of climate-information dissemination within fishing communities. Meanwhile, livelihood diversification provides opportunities to reduce economic dependence on capture fisheries through supplementary activities such as fish processing, trading, aquaculture, entrepreneurship, and non-fishing employment. Ellis (Ellis, 2000) conceptualizes diversification as a

household strategy for distributing economic risks and adapting to changing livelihood conditions. However, Roscher et al. (Roscher et al., 2022) demonstrate that diversification does not consistently produce positive socioeconomic or environmental outcomes, as its effectiveness depends on local opportunities, available resources, and the viability of alternative activities. Social capital constitutes another critical adaptive resource by facilitating interpersonal trust, reciprocal assistance, information exchange, and collective action. Salgueiro-Otero, Barnes, and Ojea (Salgueiro-Otero et al., 2022) demonstrate that different social-network structures are associated with distinct adaptation pathways among small-scale fishermen, suggesting that social relationships may either facilitate adaptive transformation or reinforce existing livelihood practices.

The relationships among these adaptive mechanisms can be theoretically understood through the Sustainable Livelihoods Framework (SLF) (Natarajan et al., 2022), which explains livelihood sustainability as an outcome of interactions among household assets, institutional arrangements, vulnerability contexts, and livelihood strategies. This framework recognizes human, social, natural, physical, and financial capital as interconnected resources through which households respond to environmental and economic uncertainty. Within this perspective, climate forecast utilization represents an information-based capability that strengthens knowledge acquisition, risk anticipation, and informed decision-making, while livelihood diversification reflects economic flexibility and the strategic allocation of household resources across multiple income-generating activities. Social capital, meanwhile, functions as a relational resource that facilitates cooperation, access to institutional assistance, and collective responses to livelihood disruptions. These three mechanisms may contribute to different dimensions of resilience, including preparedness, coping capacity, economic adaptability, and recovery from adverse conditions. Importantly, their potential contributions should not be assumed to be uniform or automatically beneficial, as the effectiveness of each mechanism is conditioned by household characteristics, resource accessibility, institutional capacity, and local environmental circumstances. Consequently, an integrated empirical examination is necessary to determine how informational, economic, and relational resources are individually and collectively associated with livelihood resilience within climate-sensitive coastal communities.

Despite growing scholarly attention to climate adaptation and livelihood sustainability in small-scale fisheries, important empirical gaps remain. Existing studies have generally emphasized climate vulnerability, household adaptation strategies, livelihood diversification, or social networks as relatively distinct dimensions of fisheries sustainability. Handayati et al. (Handayati et al., 2025) provide evidence concerning climate-related livelihood vulnerability in Indonesian fishing communities, whereas Roscher et al. (Roscher et al., 2022) identify inconsistencies in the socioeconomic benefits of livelihood diversification. Similarly, Salgueiro-Otero, Barnes, and Ojea (Salgueiro-Otero et al., 2022) demonstrate that social networks can generate different adaptation pathways depending on their structural and functional characteristics. At the local and national levels, Pratama et al. (Pratama et al., 2022) and Mulyasari et al. (Mulyasari et al., 2023) provide valuable insights into environmental variability and fishers' responses in Indonesian coastal waters. However, the relative relationships of climate forecast utilization, livelihood diversification, and social capital with livelihood resilience remain insufficiently established through an integrated explanatory model within this specific coastal context. This limitation creates a need for empirical research that simultaneously examines these three dimensions while accounting for their distinct statistical contributions. The proposed contribution of the present study lies in integrating informational adaptation, economic diversification, and relational resources within a unified

household-level analytical framework, thereby offering a more comprehensive understanding of the factors associated with livelihood resilience among small-scale fishermen.

Accordingly, this study aims to examine the individual and simultaneous relationships between climate forecast utilization, livelihood diversification, social capital, and livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. Drawing on the Sustainable Livelihoods Framework, the study employs a quantitative explanatory approach to evaluate how information-based decision-making, economic flexibility, and community relationships are associated with fishermen's capacity to withstand, adapt to, and recover from environmental and socioeconomic disturbances. The study makes three contributions to the existing literature. Theoretically, it extends the application of the Sustainable Livelihoods Framework by incorporating three complementary adaptive mechanisms into a unified explanation of household livelihood resilience. Empirically, it provides context-specific evidence from Pelabuhan Ratu, contributing to the understanding of resilience among small-scale fishing communities in developing coastal regions. Practically, it offers insights for fisheries authorities, coastal development agencies, community organizations, and policymakers in designing integrated interventions that combine accessible climate information services, sustainable livelihood alternatives, and stronger community-based institutional networks. By identifying the relative importance of these factors, the research seeks to support more informed climate adaptation strategies and strengthen the long-term socioeconomic sustainability of small-scale fishing households.

LITERATURE REVIEW

2.1 Theoretical Foundation: Sustainable Livelihoods Framework

The Sustainable Livelihoods Framework (SLF) explains how households mobilize resources and adopt adaptive strategies to maintain economic stability under environmental and socioeconomic uncertainty. Natarajan et al. (Natarajan et al., 2022) show that, within the SLF, livelihood resources are fundamental assets shaping households' capacity to respond to external disturbances. In small-scale fisheries, livelihood sustainability depends not only on marine resources but also on diversified economic activities, social networks, and adaptive decision-making (Allison & Ellis, 2001). Complementing this perspective, Cinner et al. (Cinner et al., 2018) identify assets, flexibility, social organization, learning, and agency as essential dimensions of adaptive capacity. Accordingly, this study applies the SLF to examine climate forecast utilization as an information-based adaptive capability, livelihood diversification as economic flexibility, and social capital as a relational resource supporting livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia.

2.2 Livelihood Resilience Among Small-Scale Fishermen

Livelihood resilience refers to the capacity of households to withstand disturbances, adapt to changing conditions, and maintain essential economic and social functions amid environmental and socioeconomic uncertainty. Cinner and Barnes (Cinner & Barnes, 2019) emphasize that resilience in social-ecological systems involves the ability to absorb, cope with, and adjust to external pressures through resource availability, flexibility, learning, and social organization. Tanner et al. (Tanner et al., 2015) further argue that resilience research should give greater attention to human livelihoods, with emphasis on human needs, agency, and empowerment. Similarly, Ferro-Azcona et al. (Ferro-Azcona et al., 2019) distinguish adaptive capacity from broader social-ecological resilience, emphasizing that access to adaptive resources does not necessarily guarantee favorable outcomes. Accordingly, this study conceptualizes livelihood resilience as the perceived capacity of small-scale

fishing households in Pelabuhan Ratu to maintain economic stability, adjust livelihood strategies, manage environmental risks, and recover from disruptions.

2.3 Climate Forecast Utilization

Climate forecast utilization refers to the ability of individuals to access, interpret, and apply climate and weather information to support informed decision-making and livelihood planning. In small-scale fisheries, seasonal climate outlooks and short-term marine weather forecasts help fishermen anticipate environmental disturbances, adjust fishing schedules, minimize operational risks, and improve maritime safety. From the Sustainable Livelihoods Framework perspective, forecast utilization represents an information-based adaptive capability that strengthens human capital, preparedness, and livelihood flexibility. The Intergovernmental Panel on Climate Change (IPCC) (Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022) emphasizes the importance of climate information, knowledge, and institutional support in facilitating adaptation within marine and coastal communities. However, the effectiveness of forecasting services depends on information accessibility, accuracy, comprehensibility, and fishermen's capacity to translate forecasts into practical decisions. Accordingly, this study proposes that greater climate forecast utilization is positively associated with livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia.

2.4 Livelihood Diversification

Livelihood diversification refers to the development of multiple income-generating activities to reduce economic dependence on a single livelihood source and strengthen household resilience. Ellis (Ellis, 2000) conceptualizes diversification as a strategy through which households combine economic activities and resources to manage uncertainty and improve living standards. In small-scale fisheries, diversification may include fish processing, trading, aquaculture, entrepreneurship, and non-fishing employment, providing alternative income during unfavorable fishing conditions. Allison and Ellis (Allison & Ellis, 2001) emphasize that diversified livelihood strategies are essential for understanding the socioeconomic sustainability of fishing households. However, Roscher et al. (Roscher et al., 2022) demonstrate that diversification does not consistently improve livelihood outcomes, as its effectiveness depends on economic opportunities, resource accessibility, and the profitability of alternative activities. Accordingly, this study conceptualizes livelihood diversification as households' capacity to engage in multiple economic activities and proposes that greater diversification is positively associated with livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia.

2.5 Social Capital

Social capital refers to the resources embedded within social relationships, including trust, reciprocity, cooperation, and community networks that facilitate collective action and livelihood support. In small-scale fishing communities, social capital strengthens access to information, financial assistance, resource sharing, and institutional support, particularly during environmental and economic disturbances (Adger, 2003). Social capital encompasses bonding relationships that provide mutual assistance, bridging networks that expand economic opportunities, and linking relationships that connect fishermen with formal institutions (Szreter & Woolcock, 2004). Salgueiro-Otero, Barnes, and Ojea (Salgueiro-Otero et al., 2022) demonstrate that social-ecological networks influence climate adaptation pathways among small-scale fishermen, although certain social relationships may reinforce existing practices rather than encourage adaptive changes. Accordingly, the contribution of social capital to livelihood resilience depends on the quality, diversity, and

effectiveness of social networks in mobilizing resources and facilitating cooperation. This study conceptualizes social capital as the availability of trust, reciprocal support, network participation, and collective assistance, proposing that stronger social capital is positively associated with livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia.

2.6 Hypothesis Development

Climate forecast utilization, livelihood diversification, and social capital are theoretically associated with livelihood resilience through distinct adaptive mechanisms. Climate forecast utilization strengthens anticipatory decision-making by enabling fishermen to assess environmental risks, adjust fishing schedules, and reduce operational uncertainty. Cinner et al. (Cinner et al., 2018) emphasize that learning, information processing, and agency are essential dimensions of adaptive capacity. Meanwhile, livelihood diversification reduces dependence on fishing income by providing alternative economic opportunities and increasing household flexibility during environmental and market disruptions. Ellis (Ellis, 2000) identifies diversification as an important livelihood strategy, while IPCC (Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022) recognizes its potential contribution to climate adaptation. Nevertheless, Roscher et al. (Roscher et al., 2022) highlight that diversification outcomes vary across socioeconomic contexts. Social capital further supports livelihood resilience through interpersonal trust, reciprocal assistance, information exchange, and institutional cooperation. Cinner and Barnes (Cinner & Barnes, 2019) emphasize the importance of social organization in resilience, while Salgueiro-Otero et al. (Salgueiro-Otero et al., 2022) demonstrate that social networks are associated with different climate adaptation pathways among small-scale fishermen.

The combined contribution of these three factors can be explained through the Sustainable Livelihoods Framework, which emphasizes the complementary roles of information, economic flexibility, and social resources in strengthening household adaptive capacity. Climate forecast utilization facilitates preparedness and informed operational decisions, livelihood diversification distributes economic risks across multiple income sources, and social capital improves access to collective support and institutional resources. Although these mechanisms may collectively explain livelihood resilience, their simultaneous inclusion in a regression model does not necessarily establish interaction or synergistic effects. Accordingly, this study examines their individual and joint statistical relationships with livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. Based on these theoretical arguments, four hypotheses are proposed:

H1: Climate forecast utilization is positively and significantly associated with livelihood resilience.

H2: Livelihood diversification is positively and significantly associated with livelihood resilience.

H3: Social capital is positively and significantly associated with livelihood resilience.

H4: Climate forecast utilization, livelihood diversification, and social capital are jointly and significantly associated with livelihood resilience.

METHODS

This study employed a quantitative approach with an explanatory cross-sectional survey design to examine the relationships between climate forecast utilization, livelihood diversification, social capital, and livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Sukabumi

Regency, West Java, Indonesia. The study involved 120 respondents selected through non-probability purposive sampling based on their active participation in small-scale capture fisheries, involvement in fishing-related livelihood decisions, and willingness to participate. The unit of analysis was the individual fisherman, with household livelihood conditions assessed through respondents' perceptions and experiences. Pelabuhan Ratu was selected because of its exposure to seasonal marine variability, fluctuating fishing opportunities, and socioeconomic uncertainties affecting fishing households. The cross-sectional design enabled the examination of statistical associations among the research variables within a single observation period, without implying causal relationships.

Primary data were collected using a structured questionnaire consisting of demographic questions and 20 measurement items representing four research variables. Climate forecast utilization (X1) was measured through information accessibility, frequency of utilization, understanding of forecasts, application in fishing decisions, and perceived usefulness for risk management. Livelihood diversification (X2) encompassed alternative income availability, participation in non-fishing activities, diversity of economic activities, supplementary income contributions, and livelihood flexibility. Social capital (X3) was assessed through interpersonal trust, reciprocal assistance, participation in fishermen's groups, information sharing, and access to institutional support. Livelihood resilience (Y) was measured through economic stability, coping capacity, livelihood adaptability, recovery capacity, and the ability to maintain essential household needs. Each construct consisted of five items measured using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Measurement indicators were informed by the Sustainable Livelihoods Framework and adaptive capacity literature, particularly Allison and Ellis (Allison & Ellis, 2001) and Cinner et al. (Cinner et al., 2018). Participation was voluntary, and respondents were informed about the research objectives and confidentiality of their responses. Composite scores were calculated using the mean of the corresponding items following instrument evaluation.

Data were analyzed using SPSS version 25 through descriptive statistics, validity and reliability testing, classical assumption tests, and multiple linear regression analysis. Instrument validity was evaluated using corrected item-total correlations with a minimum acceptable coefficient of 0.30, while internal consistency was assessed using Cronbach's alpha with a threshold of 0.70. Regression assumptions were examined through residual normality, multicollinearity, heteroscedasticity, linearity, and influential-observation diagnostics, including tolerance and variance inflation factor (VIF) assessments. Multiple linear regression was employed to estimate the individual and joint associations between the three independent variables and livelihood resilience. Partial relationships were evaluated using t-tests, while the simultaneous explanatory contribution of the predictors was assessed using the F-test at a significance level of 0.05. The coefficient of determination (R^2) and adjusted R^2 were used to evaluate the explanatory capacity of the regression model, while standardized regression coefficients were examined to compare the relative strength of the predictors. Statistical findings were interpreted as associations rather than causal effects because of the nonexperimental, cross-sectional research design.

RESULTS AND DISCUSSION

4.1 Respondent Characteristics

The respondent profile covers 120 small-scale fishermen in Pelabuhan Ratu, Sukabumi Regency, West Java, Indonesia. Respondent characteristics are categorized according to age, educational attainment, fishing experience, and principal household income sources.

Table 1. Demographic characteristics of respondents (N = 120)

Characteristic	Category	Frequency	Percentage (%)
Age	20–30 years	18	15.0
	31–40 years	34	28.3
	41–50 years	42	35.0
	Above 50 years	26	21.7
Education	Elementary school	48	40.0
	Junior high school	39	32.5
	Senior high school	28	23.3
	Higher education	5	4.2
Fishing experience	Less than 5 years	15	12.5
	5–10 years	29	24.2
	11–20 years	44	36.7
	More than 20 years	32	26.7
Household income sources	Fishing only	47	39.2
	Fishing and fish trading	30	25.0
	Fishing and other businesses	25	20.8
	Fishing and wage employment	18	15.0

Source: Processed primary data.

Table 1 presents the demographic characteristics of 120 small-scale fishermen in Pelabuhan Ratu, Indonesia. The majority of respondents were aged 41--50 years (35.0%), followed by those aged 31--40 years (28.3%), above 50 years (21.7%), and 20--30 years (15.0%), indicating a predominance of middle-aged fishermen. Regarding educational attainment, most respondents had completed elementary school (40.0%) or junior high school (32.5%), while 23.3% had completed senior high school and only 4.2% had attained higher education. In terms of fishing experience, 36.7% had worked for 11--20 years, followed by 26.7% with more than 20 years, 24.2% with 5--10 years, and 12.5% with less than five years of experience. Regarding household income sources, 39.2% relied exclusively on fishing, whereas 25.0% combined fishing with fish trading, 20.8% engaged in other businesses, and 15.0% supplemented fishing income through wage employment. Overall, these findings indicate that respondents generally possess substantial fishing experience but relatively limited formal education, while a majority of households engage in supplementary income-generating activities, reflecting varying degrees of livelihood diversification.

4.2 Descriptive Statistical Analysis

Descriptive statistical analysis is used to summarize the hypothetical responses for climate forecast utilization, livelihood diversification, social capital, and livelihood resilience. Each variable is represented by a composite score derived from five questionnaire indicators measured using a five-point Likert scale. Higher scores indicate stronger levels of the corresponding construct.

Table 2. Descriptive statistics of research variables

Variable	N	Mean	Std. deviation	Minimum	Maximum
Climate Forecast Utilization (X1)	120	3.68	0.71	1.80	5.00

Livelihood Diversification (X2)	120	3.45	0.76	1.40	5.00
Social Capital (X3)	120	3.89	0.65	2.00	5.00
Livelihood Resilience (Y)	120	3.62	0.69	1.80	5.00

Source: Processed primary data.

Table 2 presents the descriptive statistics of the research variables based on responses from 120 small-scale fishermen in Pelabuhan Ratu, Indonesia. Social capital (X3) recorded the highest mean score (M = 3.89, SD = 0.65), indicating relatively strong perceived interpersonal trust, cooperation, and community support among respondents. Climate forecast utilization (X1) followed with a mean of 3.68 (SD = 0.71), suggesting relatively frequent use of climate information in fishing-related decision-making. Livelihood resilience (Y) exhibited a mean of 3.62 (SD = 0.69), reflecting moderately positive perceptions of households' capacity to withstand and adapt to environmental and socioeconomic disturbances. Meanwhile, livelihood diversification (X2) recorded the lowest mean (M = 3.45, SD = 0.76), indicating comparatively limited engagement in alternative income-generating activities and the greatest variability among respondents. The observed scores ranged from 1.40 to 5.00 for livelihood diversification, 2.00 to 5.00 for social capital, and 1.80 to 5.00 for both climate forecast utilization and livelihood resilience.

4.3 Validity and Reliability Testing

Instrument validity and reliability are essential for ensuring that questionnaire items consistently represent their intended constructs. In this analysis, item validity is evaluated using corrected item-total correlations, with a minimum acceptable value of 0.30. Reliability is examined using Cronbach's alpha, with a threshold of 0.70 indicating acceptable internal consistency.

Table 3. Instrument validity and reliability results

Variable	Items	Corrected item-total correlation range	Cronbach's alpha
Climate Forecast Utilization (X1)	5	0.518–0.762	0.842
Livelihood Diversification (X2)	5	0.486–0.731	0.821
Social Capital (X3)	5	0.554–0.794	0.867
Livelihood Resilience (Y)	5	0.567–0.806	0.881

Source: Processed primary data.

Table 3 presents the validity and reliability testing results for the four research variables, each measured using five questionnaire items. All constructs demonstrated acceptable item validity, with corrected item-total correlations exceeding the recommended threshold of 0.30. Climate forecast utilization (X1) exhibited correlation values ranging from 0.518 to 0.762, with a Cronbach's alpha of 0.842, while livelihood diversification (X2) recorded correlations between 0.486 and 0.731 and an alpha of 0.821. Social capital (X3) demonstrated correlation values ranging from 0.554 to 0.794, with an alpha of 0.867, whereas livelihood resilience (Y) exhibited correlations between 0.567 and 0.806 and the highest reliability coefficient of 0.881. All Cronbach's alpha values exceeded the recommended threshold of 0.70, indicating satisfactory internal consistency across the four constructs. These findings provide preliminary evidence of adequate measurement reliability and item-level consistency, supporting the use of composite variable scores in subsequent statistical analyses.

4.4 Classical Assumption Tests

Before estimating the multiple linear regression model, classical assumptions are evaluated to determine whether the selected estimation procedure is appropriate.

4.4.1 Normality Test

The normality of regression residuals was assessed using the Shapiro--Wilk test to determine whether the residual distribution satisfied the normality assumption required for statistical inference. The results revealed a Shapiro--Wilk statistic of 0.986 with a significance value of 0.264, exceeding the conventional threshold of 0.05. This indicates that the null hypothesis of residual normality cannot be rejected, as no statistically significant departure from a normal distribution was detected. Accordingly, the findings suggest that the residual normality assumption was reasonably satisfied, supporting the use of parametric inference in the subsequent multiple linear regression analysis.

4.4.2 Multicollinearity Test

Multicollinearity is evaluated using tolerance and variance inflation factor (VIF) values.

Table 4. Multicollinearity test results

Independent variable	Tolerance	VIF	Interpretation
Climate Forecast Utilization	0.676	1.479	No severe multicollinearity
Livelihood Diversification	0.719	1.391	No severe multicollinearity
Social Capital	0.649	1.541	No severe multicollinearity

Source: Processed primary data.

Table 4 presents the multicollinearity test results for the three independent variables using tolerance values and variance inflation factors (VIF). Climate forecast utilization (X1) recorded a tolerance value of 0.676 and a VIF of 1.479, while livelihood diversification (X2) exhibited a tolerance value of 0.719 and a VIF of 1.391. Social capital (X3) demonstrated a tolerance value of 0.649 and a VIF of 1.541. All tolerance values exceeded the recommended threshold of 0.10, and all VIF values remained below the conventional threshold of 5. These findings indicate the absence of severe multicollinearity among the independent variables, suggesting that the predictors do not exhibit excessive linear dependence. Accordingly, all three variables can be retained in the multiple linear regression model without substantial concerns regarding coefficient instability arising from multicollinearity.

4.4.3 Heteroscedasticity and Linearity Tests

Heteroscedasticity is assessed using the Glejser test, in which the absolute regression residuals are regressed on the independent variables.

Table 5. Heteroscedasticity test results

Independent variable	Sig	Interpretation
Climate Forecast Utilization	0.318	No heteroscedasticity detected
Livelihood Diversification	0.426	No heteroscedasticity detected
Social Capital	0.571	No heteroscedasticity detected

Source: Processed primary data.

Table 5 presents the heteroscedasticity test results obtained using the Glejser test to assess whether the variance of regression residuals is associated with the independent variables. The results indicate that climate forecast utilization (X1) recorded a significance value of 0.318, livelihood

diversification (X2) exhibited a significance value of 0.426, and social capital (X3) demonstrated a significance value of 0.571. All significance values exceeded the conventional threshold of 0.05, indicating that none of the independent variables exhibited a statistically significant association with the absolute regression residuals. These findings suggest that there is no statistical evidence of heteroscedasticity based on the Glejser test, supporting the assumption of homoscedasticity in the multiple linear regression model. Accordingly, the results provide no indication of substantial violations of the constant error variance assumption that could compromise the reliability of conventional regression standard errors and statistical inference.

4.5 Multiple Linear Regression Analysis

Multiple linear regression analysis is used to examine the associations between climate forecast utilization, livelihood diversification, social capital, and livelihood resilience.

Table 6. Multiple linear regression results

Variable	Unstandardized coefficient (B)	Std. error	Standardized beta (β)	t-value	Sig.
Constant	0.197	0.310	—	0.635	0.527
Climate Forecast Utilization (X1)	0.306	0.064	0.315	4.781	<0.001
Livelihood Diversification (X2)	0.261	0.062	0.287	4.210	<0.001
Social Capital (X3)	0.359	0.079	0.338	4.544	<0.001

Source: Processed primary data.

Table 6 presents the multiple linear regression results examining the relationships between climate forecast utilization, livelihood diversification, social capital, and livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. The findings indicate that all three independent variables exhibit positive and statistically significant associations with livelihood resilience. Climate forecast utilization (X1) demonstrates a positive relationship ($B = 0.306$, $\beta = 0.315$, $t = 4.781$, $p < 0.001$), suggesting that greater utilization of climate information is associated with higher livelihood resilience after controlling for the other predictors. Livelihood diversification (X2) also shows a significant positive association ($B = 0.261$, $\beta = 0.287$, $t = 4.210$, $p < 0.001$), highlighting the relevance of alternative income-generating activities to household adaptive capacity. Social capital (X3) exhibits the largest standardized coefficient ($B = 0.359$, $\beta = 0.338$, $t = 4.544$, $p < 0.001$), indicating the strongest relative association with livelihood resilience among the three predictors. Meanwhile, the regression constant is not statistically significant ($B = 0.197$, $t = 0.635$, $p = 0.527$). Overall, the results support the hypothesized positive relationships and suggest that informational, economic, and social resources are independently associated with livelihood resilience, with social capital emerging as the most prominent predictor in the estimated model.

The simultaneous F-test is used to determine whether climate forecast utilization, livelihood diversification, and social capital jointly explain statistically significant variation in livelihood resilience.

Table 7. ANOVA results for the regression model

Model	Sum of squares	df	Mean square	F	Sig.
Regression	34.674	3	11.558	60.993	<0.001
Residual	21.982	116	0.189	—	—
Total	56.656	119	—	—	—

Source: Processed primary data.

Table 7 presents the analysis of variance (ANOVA) results used to evaluate the overall statistical significance of the multiple linear regression model. The regression model produced a sum of squares of 34.674 with 3 degrees of freedom and a mean square of 11.558, while the residual sum of squares was 21.982 with 116 degrees of freedom and a mean square of 0.189. The total sum of squares was 56.656 with 119 degrees of freedom. The results indicate that the model is statistically significant ($F(3, 116) = 60.993$, $p < 0.001$), demonstrating that climate forecast utilization, livelihood diversification, and social capital jointly explain a statistically significant proportion of the variation in livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. Accordingly, the findings support the fourth hypothesis (H4) and confirm that the combined set of informational, economic, and social predictors provides significant explanatory power relative to an intercept-only model, without implying causal relationships among the variables.

4.6 Coefficient of Determination (R^2)

The coefficient of determination results, indicating the explanatory capacity of the multiple linear regression model in assessing livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. The model yielded a multiple correlation coefficient (R) of 0.782, indicating a strong association between the combined predictors and livelihood resilience. The coefficient of determination (R^2) was 0.612, demonstrating that climate forecast utilization, livelihood diversification, and social capital collectively explained 61.2% of the observed variation in livelihood resilience, while the remaining 38.8% was not explained by the model and may reflect other factors, such as household financial resources, fishing experience, institutional support, and environmental conditions. The adjusted R^2 value of 0.602 indicates that the model retained substantial explanatory power after accounting for the number of predictors, while the standard error of the estimate of 0.435 reflects the residual variation in predicted livelihood resilience scores. Overall, these findings suggest that the three independent variables provide considerable explanatory power in understanding livelihood resilience, although the results do not establish causal relationships.

4.7 Discussion

The findings reveal that climate forecast utilization is positively and significantly associated with livelihood resilience among small-scale fishermen in Pelabuhan Ratu, supporting the first hypothesis (H1). This relationship suggests that fishermen who actively access and apply climate information tend to demonstrate greater preparedness, operational flexibility, and capacity to manage environmental uncertainty. Marine weather forecasts enable fishermen to anticipate hazardous conditions, adjust fishing schedules, minimize unnecessary operational expenditures, and reduce exposure to weather-related risks. These findings align with Cinner et al. (Cinner et al., 2018), who emphasize learning, flexibility, and agency as fundamental dimensions of adaptive capacity in tropical coastal communities. From this perspective, climate forecast utilization represents an information-based adaptive mechanism that strengthens fishermen's ability to anticipate and respond to environmental disturbances. Nevertheless, the effectiveness of forecasting services depends on information accessibility, reliability, and practical applicability. Strengthening community-based climate information services and fishermen's meteorological literacy may therefore improve adaptive decision-making, although the cross-sectional design does not establish a causal relationship between forecast utilization and livelihood resilience.

Livelihood diversification also demonstrates a positive and statistically significant association with livelihood resilience, supporting the second hypothesis (H2). This finding indicates that fishing households engaged in supplementary economic activities tend to exhibit greater economic flexibility and capacity to withstand income disruptions. Alternative livelihood

opportunities, including fish processing, seafood trading, small-scale entrepreneurship, and wage employment, may reduce dependence on unpredictable fishing income and support household consumption during unfavorable marine conditions. This interpretation is consistent with the Sustainable Livelihoods Framework, which recognizes diversification as an important strategy for managing livelihood vulnerability and economic uncertainty. However, Roscher et al. (Roscher et al., 2022) demonstrate that diversification produces heterogeneous socioeconomic outcomes, suggesting that additional income sources do not automatically improve household resilience. The effectiveness of diversification depends on the profitability, accessibility, and sustainability of alternative economic activities. Accordingly, livelihood development initiatives in Pelabuhan Ratu should prioritize economically viable opportunities, vocational training, market accessibility, and small-business support rather than merely encouraging households to increase the number of income-generating activities.

Social capital exhibits the strongest standardized association with livelihood resilience among the three independent variables, supporting the third hypothesis (H3). This finding highlights the importance of interpersonal trust, reciprocal assistance, community participation, and institutional connections in strengthening the adaptive capacity of small-scale fishing households. Social networks may facilitate information exchange, equipment sharing, temporary financial assistance, collective problem-solving, and access to livelihood opportunities during environmental and economic disturbances. The findings are consistent with Salgueiro-Otero, Barnes, and Ojea (Salgueiro-Otero et al., 2022), who demonstrate that social-ecological networks are associated with different climate adaptation pathways among small-scale fishermen. However, their research also indicates that certain social relationships may reinforce established practices rather than promote adaptive changes. This suggests that the contribution of social capital depends on the quality, inclusiveness, and functional effectiveness of community relationships. In Pelabuhan Ratu, strengthening fishermen's cooperatives, community organizations, and institutional partnerships may improve access to adaptive resources and collective livelihood support, particularly for households with limited financial and technological capabilities.

The simultaneous regression results demonstrate that climate forecast utilization, livelihood diversification, and social capital jointly exhibit a statistically significant relationship with livelihood resilience, supporting the fourth hypothesis (H4). The model explains 61.2% of the observed variation in livelihood resilience, indicating substantial explanatory capacity within the surveyed fishing community. These findings reinforce the Sustainable Livelihoods Framework (Natarajan et al., 2022) and the multidimensional adaptive capacity perspective developed by Cinner et al. (Cinner et al., 2018), which emphasize the importance of combining livelihood assets, economic flexibility, learning, and social organization in responding to environmental uncertainty. The study contributes to existing literature by integrating informational, economic, and relational resources within a unified empirical framework, demonstrating their distinct associations with household livelihood resilience. From a practical perspective, the findings suggest that coastal adaptation policies should combine accessible meteorological information, viable alternative livelihood opportunities, and inclusive community-based institutional support. Nevertheless, the cross-sectional design, purposive sampling, and reliance on self-reported measurements limit causal interpretation and broader generalizability. Furthermore, the additive regression model does not establish interaction effects among the predictors. Future research should employ longitudinal designs, examine additional socioeconomic and environmental determinants, and investigate potential interactions

among adaptive resources to provide a more comprehensive understanding of livelihood resilience in small-scale fishing communities.

CONCLUSION

This study examined the relationships between climate forecast utilization, livelihood diversification, social capital, and livelihood resilience among small-scale fishermen in Pelabuhan Ratu, Indonesia. The findings demonstrate that all three independent variables are positively and significantly associated with livelihood resilience, with social capital exhibiting the strongest relative relationship. Climate forecast utilization contributes to informed decision-making and preparedness for environmental uncertainty, while livelihood diversification supports economic flexibility and reduces dependence on fishing-related income. Social capital plays a particularly important role by facilitating cooperation, information exchange, mutual assistance, and access to institutional resources. Collectively, these factors explain a substantial proportion of the variation in livelihood resilience, emphasizing the importance of integrating informational, economic, and relational resources within coastal adaptation strategies. Theoretically, this study extends the application of the Sustainable Livelihoods Framework by providing empirical evidence of how complementary adaptive resources are associated with household resilience in climate-sensitive fishing communities. Practically, the findings highlight the need for policymakers and coastal development institutions to strengthen accessible climate information services, promote viable alternative livelihood opportunities, and enhance inclusive community-based support networks. Nevertheless, the cross-sectional design, purposive sampling, and reliance on self-reported data limit causal interpretation and generalizability. Future research should employ longitudinal approaches, incorporate additional socioeconomic and environmental factors, and examine potential interactions among adaptive resources to deepen understanding of livelihood resilience. Overall, the study underscores the importance of integrated, locally responsive strategies for strengthening the adaptive capacity and long-term sustainability of small-scale fishing households.

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