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Adaptation Strategies of Small-Scale Fishermen Households to Climate Change Impacts: Evidence from North Lombok, Indonesia

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Abstract

Climate change has significantly affected the livelihoods of small-scale fishermen households in North Lombok Regency, the region with the highest poverty rate in West Nusa Tenggara Province, Indonesia. This study aims to identify the livelihood sources of small-scale fisher households and assess the impacts of climate change on those sources, as well as to formulate adaptation strategies to cope with the impacts of climate change. A mixed-methods approach was applied. Data were collected through structured interviews with 100 respondents. Data were analyzed using the Analytical Hierarchy Process (AHP). The results show that household livelihoods rely mainly on fishing activities (by husbands), contributing the highest income (IDR 1,837,908/month), followed by non-fishing activities (IDR 598,250/month). Additional income is generated by wives and children, averaging IDR 796,650 and IDR 361,000 per month, respectively. Climate change has reduced fishing activity and income, threatening the sustainability of these livelihoods. In response, adaptation strategies include diversification of fishing gear and techniques, development of alternative income sources, use of fishing information technology, access to government support, adjustment of fishing times and locations, mangrove and coral reef restoration, social network utilization, and use of household assets and savings.These strategies reflect the adaptive efforts of small-scale fishermen households to maintain and strengthen their livelihoods amid climate-related challenges.

Keywords: Adaptation strategies, Small-scale fishermen households, Climate Change, AHP.

1. Introduction

Indonesia is highly vulnerable to the impacts of climate change. This vulnerability is closely related to the country's geographical characteristics—comprising mostly ocean, with a sea area of 5.8 million km², a coastline of 81,000 km, and 17,508 islands (Nursan et al., 2022). Indonesia ranks 37th out of 182 countries most affected by climate change (Eckstein et al., 2017). Among

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the 323 regencies and cities in Indonesia, 23 regions are significantly affected by climate change (Suroso et al., 2011).

Climate change in Indonesia has already posed serious threats to human lives (Rondhi et al., 2019; Steffen et al., 2015), the global environment (Čadro et al., 2019; Simunic et al., 2019) and biodiversity (Kroeker et al., 2013; Wenger et al., 2011). It contributes to food shortages, migration, heatwaves, droughts, tidal floods, storms, forest fires, and degradation of marine ecosystems (IPCC, 2013; Rahman & Rahman, 2015; Zougmoré et al., 2019). These changes reduce the availability of marine resources and organisms (Comte & Olden, 2017; Knouft & Ficklin, 2017). significantly affecting small-scale fishermen households—many of whom are still poor (Nielsen et al., 2018) and heavily reliant on the sea for their livelihood and food supply (Lauria et al., 2018). The fisheries sector, though critical for household livelihoods and food security, remains highly vulnerable to climate change (Galappaththi et al., 2022).

To understand how fishing communities respond to climate pressures, it is essential to apply relevant theoretical perspectives. Human adaptation theory explains how individuals and communities adjust behaviorally and structurally to environmental changes (Ojea et al., 2020). The Sustainable Livelihood Framework (SLF) underscores five categories of capital—natural, financial, human, social, and physical—that collectively influence the adaptive capacity of households (Afrin & Islam, 2023). Meanwhile, the Progressive-Integrative Social Structure (S2PI) model highlights the dynamic interaction between individual agency and social institutions in shaping community responses, aligning with integrative approaches to climate adaptation (Fedele et al., 2019). These frameworks are conceptually relevant for examining how small-scale fishermen adapt within their specific socio-ecological contexts.

Social structures such as patron-client systems, kinship networks, and community-based organizations strongly influence decision-making processes and resource access. These social structures can either constrain or enable adaptation strategies, depending on how inclusive and responsive they are to change. Recognizing these dynamics is crucial in identifying realistic and sustainable adaptation pathways for fishermen households.

North Lombok Regency in West Nusa Tenggara Province is one such coastal area impacted by climate change. Migration of fishing communities from this region has already occurred due to climate-related pressures (Hidayati et al., 2021; Latifa & Romdiati, 2017). Moreover, North Lombok is the only region in the province still designated as a "3T" area (underdeveloped, frontier,

and outermost). It has the highest poverty rate in the province, with 61,700 people (27.04%) living in poverty. The poverty depth index is 5.69, and the severity index is 1.66. Additionally, 1,043 individuals (0.41%) fall into the extreme poverty category out of a total population of 256,438 (BPS North Lombok Regency, 2022). The extremely poor population is predominantly composed of fishermen and farmer households, who are highly vulnerable to climate impacts on their livelihoods. Adaptation strategies are needed for small-scale fishermen households to overcome the impacts of climate change.

Climate change adaptation policies in the fisheries sector remain largely sectoral and short-term, often neglecting the role of local social structures and community-based capacities. In fact, small-scale fishing communities possess unique social systems and adaptive strategies that can inform more context-specific and responsive policy design. This study introduces a novel approach by integrating the Analytical Hierarchy Process (AHP) with three conceptual frameworks: human adaptation theory, the Progressive-Integrative Social Structure (S2PI) model, and the Sustainable Livelihood Framework (SLF). This integration enables a multidimensional analysis of adaptation strategies, considering not only economic impacts but also the influence of social relations, social capital, and institutional support in enhancing household resilience to climate change.

This study aims to assess the impacts of climate change on these sources and formulate adaptation strategies for small-scale fishermen households.

2. Materials and methods

This research uses mixed methods of quantitative and qualitative. The research was conducted in four villages in North Lombok Regency: Gondang Village in Gangga District, and Jenggala, Sigar Penjalin, and Tanjung Villages in Tanjung District. These villages were purposely selected due to their exposure to extreme weather events. The locations are shown in Figure 1.

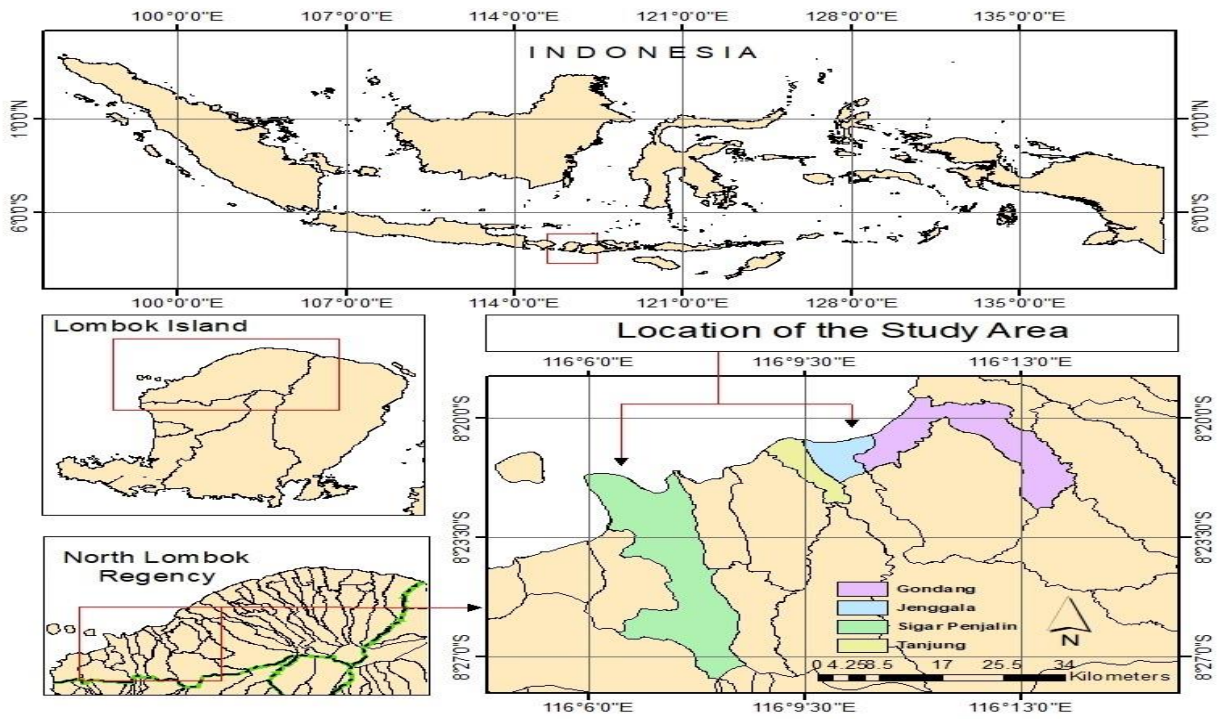

Figure 1. Regional Map of Study Location (North Lombok Regency, Lombok Island, Indonesia).

Data collection was conducted from June to September 2024. A total of 100 respondents were selected from a population of 412 small-scale fishing households using Slovin's formula, with an error margin of 8.7%. The sample was proportionally allocated across four purposively selected coastal villages: Gondang (36), Singgar Penjalin (23), Jenggala (25), and Tanjung (16). Respondents were chosen using simple random sampling based on an official household list. Data were collected through structured interviews and focus group discussions (FGDs), and analyzed using the Analytic Hierarchy Process (AHP) with Criterium DecisionPlus (CDP) Program to prioritize adaptation strategies. AHP analysis is a decision analysis technique based on various alternatives, criteria and objectives (Büyüközkan et al., 2019; Dehghanimohammadabadi & Kabadayi, 2020). The following are the steps in AHP analysis (Saaty, 1980):

1. Conducting problem analysis.
2. Carrying out pairwise comparisons (*pairwise comparison*). The hierarchical weighting is presented in Table 1.

Table 1. Weight Values for Each Hierarchy Level.

Weight	Definition
1	Both elements are equally important
3	One element is slightly more important than the others
5	One element is more important than the other
7	One element is clearly more important than the others
9	One element is absolutely more important than the others
2, 4, 6, 8	Values between two adjacent results

Source: Saaty (1980).

3. Calculating eigenvalues and eigenvectors.
4. Checking the consistency of the comparison matrix.
5. Summarizing priorities to make decisions.

3. Results and Discussions

Sources of Livelihood for Small-scale Fishermen Households

The sources of livelihood for small-scale fishermen households in North Lombok Regency comes from the main activity of fishing, businesses in the fisheries sector and outside the fisheries sector. The largest household income for small-scale fishermen comes from the main source of income, i.e., fishing (by husband) amounting to IDR 1,837,908 per month, then non fishing (by husband) of only IDR 598,250 per month. The income of wives and children to support the household economy of small-scale fishermen households is IDR 796,650 and IDR 361,000 per month. Fishing is an activity that provides the largest contribution to household income compared to other activities, as also found by Mpemba and Mombo (2019).

The Impact of Climate Change on the Source of Livelihood of Small-scale Fishermen Households

The impact of climate change on the livelihoods of small-scale fishermen households in North Lombok Regency can be seen from the case of activity and the amount of fishing caught over the last 10 years. The results of the analysis are presented in Table 2.

Table 2. The impact of climate change on the livelihoods of Small-scale Fishermen Households in North Lombok Regency (2024).

No	Description	Percentage (%)
	Climate change causes fishing activities to be:	
1	Easy	0
2	Difficult	89
3	No difference	11
	Amount	100
	Climate change cause result of fish catch to:	
1	Increase	0
2	Decrease	76
3	No difference	24
	Amount	100

The majority of fishermen (89%) reported that fishing activities have become more difficult over the past 10 years due to climate change, while 11% reported no change. Additionally, 76% of fishermen stated that their catches have decreased as a result of climate change, whereas 24% saw no difference. This difficulty and reduction in catches are caused by shifts to more remote fishing areas and decreased fishing intensity due to longer periods of not fishing, driven by climate-related events such as rising sea levels, storms, floods, and coastal erosion (Barange et al., 2018). Therefore, climate change that has occurred in North Lombok Regency has had an impact on reducing the income of small fishermen from their main source of income, the fishing. These results are in line with research by (Shaffril et al., 2017) who found that climate change has reduced fishing intensity by up to 90% a month during the northeast season and reduced fishermen source of livelihood and income (Bah et al., 2018; Chan et al., 2023).

Small-scale Fishermen Households Adaptation Strategy to Climate Change

There are 8 alternative strategies used by Small-scale fishermen Households to overcome the impacts of climate change in North Lombok Regency. The details of these alternative strategies are presented in Table 3, and then each strategy is explained in more details.

Table 3. Adaptation strategies of Small-scale Fishermen Households in overcoming the impacts of climate change in North Lombok Regency.

No	Adaptation Strategy	Code	Percentage (%)
1	Receiving Government Assistance	S1	100
2	Diversification of fishing equipment and techniques	S2	100
3	Change of Capture time and region	S3	58
4	Use of information technology in fishing	S4	38
5	Diversification of household income sources	S5	59
6	Utilization of Assets and Savings	S6	61
7	Social network	S7	46
8	Planting Mangroves and Coral Reefs	S8	26

Receiving government assistance

Small-scale fishermen households in North Lombok Regency are tackling the impacts of climate change with assistance from the local government, which provides 10 kg of rice per family. This support is universal among households and is complemented by the provision of fishing equipment, such as nets and boats, along with training on climate-resilient coastal practices. While these government interventions help mitigate risks and vulnerabilities, challenges remain, including insufficient aid and distribution delays, raising concerns about dependency due to a lack of capacity-building initiatives. To improve the situation, government policies should focus on increasing the adequacy of aid, ensuring timely and transparent distribution with community oversight, and implementing sustainable empowerment programs. Furthermore, these policies align with the findings of Celliers et al. (2013) for integrated support systems to help vulnerable coastal communities adapt to climate change effectively.

Diversification of Fishing equipment and techniques

Small-scale fishermen can mitigate the impacts of climate change by diversifying their fishing equipment and techniques. Previously, fishing was relatively easy, but rising temperatures and sea levels have made it more challenging. As a result, small fishermen are compelled to expand the types of fishing gear and methods they use to catch specific fish species. In North Lombok Regency, 100 percent of fishermen have diversified their equipment and techniques to adapt to these changes. This strategy is in accord with Badjeck et al., (2010), that one of the factors that can help fishermen livelihoods in overcoming the impacts of climate change is by changing new fishing techniques and tools.

Change of capture time and location

Climate change has compelled fishermen to change their fishing grounds, leading to the loss of traditional areas and a shift to more distant locations. While they often rely on their instincts and experience to discover new fishing spots that might be rich in fish, this adaptation comes with challenges. Increased operational costs, such as a 15–20% rise in fuel expenses, along with time wasted on trial-and-error in unfamiliar waters, can result in lower catch volumes—sometimes decreasing by up to 30% during certain seasons. These difficulties can make new fishing areas less profitable, especially due to unfamiliar environments, fewer available species, and heightened competition. In North Lombok Regency, fishermen take into account their past experiences,

weather information, and advice from peers when determining new fishing times and locations, with 58 percent having adjusted their practices to adapt to these changes. This strategy aligns with findings from Lédée et al., (2012) and Comte et al., (2013), which observed similar spatial adaptations in response to climate-driven changes in fish availability. We recommend providing fuel subsidies, improving access to weather forecasting, and establishing cooperative planning among communities to facilitate this transition.

Use of information technology in fishing

Climate change has made it challenging for fishermen to predict weather conditions and fishing seasons, which were previously based on natural signs and experience. To adapt, fishermen are now using information technology, such as weather forecasts from BMKG (the meteorological agency), television, the internet, cell phones, and information from local governments. However, in North Lombok Regency, access to fish-catching technology information is low, with only about 38 percent of fishermen utilizing fishing information technology, market information, and fishery product processing technology. Barriers to adoption include limited digital literacy, particularly among older fishermen; high costs of mobile data and smartphone access; and poor internet connectivity in coastal and remote villages. Suggested interventions include digital literacy training, subsidized access to fishing-related apps, and infrastructure development in low-connectivity areas. Research by Galappaththi et al., (2019) and Musinguzi et al., (2016) supports the importance of increasing access to technology and information in enhancing climate resilience.

Diversification of household income sources

Diversifying household income sources is a crucial strategy for small fishing households in North Lombok Regency to adapt to the impacts of climate change and reduce reliance on a single income source. This livelihood diversification has been implemented by 59 percent of small-scale fishermen households, who have found additional sources of income beyond fishing. This other source of income is provided by fishermen when they are not fishing and there are extreme weather changes. Fishermen will look for additional work when the non-fishing season starts (Paulus et al., 2019; Taufik et al., 2023). Fishermen engage in these activities to support their families and ensure their survival. In North Lombok Regency, fishermen households have various sources of income, including roles as farmers, agricultural laborers, fishing workers, carpenters, air conditioning technicians, livestock breeders, government employees, drivers, builders, and security guards.

Additionally, many wives assist their husbands by selling fish and essential goods, while children often take on jobs in the private sector or become migrant workers. Several studies have found that diversifying household sources of income can increase the resilience of coastal communities to climate change (Badjeck et al., 2010; Pinsky & Mantua, 2014; Ojea et al., 2017).

Utilization of Assets and Savings

Small-scale fishermen households rely on assets and savings to meet daily needs and support fishing activities. About 61% adapt by selling items like livestock, gold, or vehicles to fund operations and cope with economic pressures. Research by Berman et al., (2015), found that selling assets and saving can be done to overcome the impact of climate change on households in Western Uganda.

Social networks

To cope with climate change, small-scale fishermen households in North Lombok Regency rely on their social networks as an adaptation strategy, with 46% of fishermen utilizing these networks. These social networks include horizontal connections, such as fishermen's groups, which serve as forums for exchanging ideas about fishing practices. They also involve social borrowing, where fishermen borrow money for daily needs from private moneylenders. Additionally, fishermen engage in vertical networks by receiving government programs and assistance, including food, boats, and fishing gear. Some fishermen also borrow money from banks. Collaborative and joint action strategies are essential to effectively reduce the impacts of climate change (Galappaththi et al., 2019).

Planting Mangroves and Coral Reefs

Fishermen in North Lombok Regency are actively working to restore their environment in response to climate change by planting coral reefs and mangroves. This initiative aims to preserve fish habitats and protect coastal ecosystems. While 26% of fishermen recognize the environmental damage, these restoration efforts are also supported by community organizations to enhance ecosystem preservation and attract tourism. However, the adoption of these practices is hindered by high costs, the need for technical knowledge, limited immediate benefits, and uncertainty regarding the survival of the planted corals and mangroves. For many households facing financial constraints, these challenges are significant. To encourage broader community participation,

supportive policies and training programs are essential. Mangroves and coral reefs are crucial for reducing the climate vulnerability of coastal areas (Guannel et al., 2016) and play a vital role in their sustainable development (Chow, 2017).

Adaptation strategies priority for small-scale Fishermen households to climate change

Determining the priority of adaptation strategies for small-scale fishermen households in overcoming the impacts of climate change in North Lombok Regency was carried out using AHP analysis. This analysis was first introduced by Saaty (1980) to assist decision making that involves many factors and assessment criteria and alternatives.

Determination of adaptation strategy criteria

Determining the criteria for adaptation strategies for small-scale fishermen households in overcoming the impacts of climate change in North Lombok Regency was carried out by experts. The selected criteria are economic, social, ecological, policy and technological criteria. The results of the AHP analysis of priority selection criteria can be seen in Table 4.

Table 4. Determining priority criteria for adaptation strategies for small-scale Fishermen households in overcoming the impacts of climate change in North Lombok Regency.

Criterion	Economy	Social	Ecology	Policy	Technology	Eigenvalues	Ranking
Economy	1.000	2.000	1.000	3.000	2.000	0.311	1
Social	0.500	1.000	1.000	0.500	0.333	0.108	5
Ecology	1.000	1.000	1.000	1.000	0.333	0.150	3
Policy	0.333	2.000	1.000	1.000	0.333	0.130	4
Technology	0.500	3.000	3.000	3.000	1.000	0.302	2
CR						0.081	

Table 4 shows that economic criteria are a priority in determining adaptation strategies for small-scale Fishermen households in overcoming the impacts of climate change with a value of 0.311, followed by technological criteria of 0.302, ecology of 0.150, policies of 0.130 and social criteria of 0.108. Assessment by experts regarding the priority of these criteria shows consistent results, indicated by the consistency ratio (CR) value of 0.1 or less, that is 0.081.

Priority Adaptation Strategy for Small-scale Fishermen households

After analyzing the criteria and selecting strategies based on existing criteria, the priority adaptation strategies for small-scale fishermen households can be determined in overcoming the

impacts of climate change in North Lombok Regency. The results of AHP to determine the adaptation priority strategy can be seen in Table 5.

Table 5. Result of AHP to determine priority adaptation strategies for small-scale Fishermen households in overcoming the impacts of climate change in North Lombok Regency.

Criterion	S1	S2	S3	S4	S5	S6	S7	S8	Model Weights
Economic	0.109	0.199	0.077	0.150	0.272	0.073	0.061	0.059	0.311
Social	0.209	0.070	0.05	0.107	0.141	0.07	0.237	0.116	0.108
Ecology	0.092	0.176	0.085	0.188	0.249	0.049	0.049	0.111	0.149
Policy	0.199	0.215	0.148	0.102	0.099	0.065	0.057	0.115	0.13
Technology	0.121	0.246	0.128	0.201	0.101	0.055	0.047	0.102	0.302
Results	**0.133**	**0.198**	**0.100**	**0.160**	**0.180**	**0.063**	**0.074**	**0.093**	
Ranking	4	1	5	3	2	8	7	6	

The AHP analysis for small-scale fishermen households in North Lombok Regency identified S2 as the top priority adaptation strategy with a value of 0.198, followed by S5 (0.180), S4 (0.160), S1 (0.133), S3 (0.100), S8 (0.093), S7 (0.074), and S6 (0.063).

The priority adaptation strategies for small-scale fishermen households in overcoming the impacts of climate change can be seen in Figure 2.

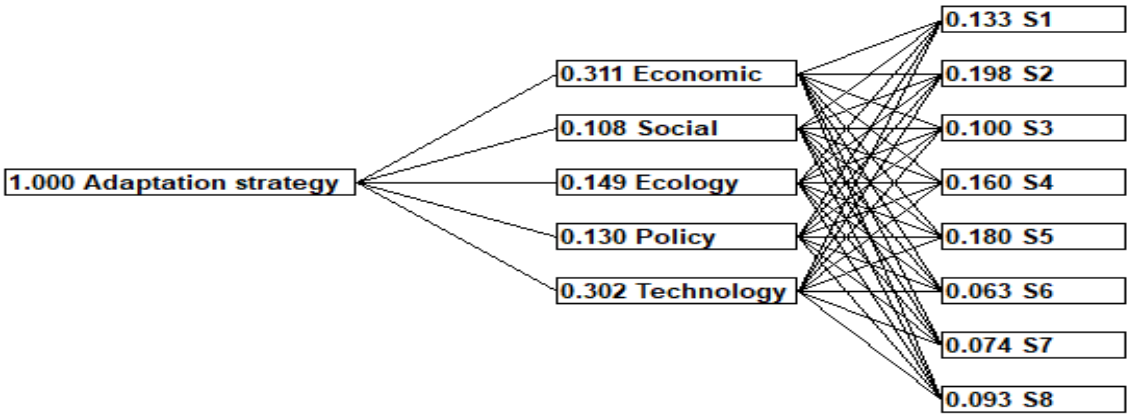

Figure 2. Adaptation strategies priority for small-scale fishermen households.

In order to survive and reduce the impacts of climate change, small-scale households must adopt appropriate adaptation strategies (Pescaroli et al., 2023). In line with this, the findings of this study indicate that fishermen should prioritize adaptation strategies that encompass cognitive, practical, and organizational aspects in addressing the challenges posed by climate change (Samah et al., 2016).

The study identifies eight key adaptation strategies used by small-scale fishing households to cope with climate change, including diversification of fishing gear and income, government aid, use of technology, social network strengthening, and environmental restoration. Quantitative analysis

highlights diversification as a top priority, but adaptive capacity also depends heavily on social capital, savings, and information access, emphasizing the role of institutional support.

Policy implications call for systemic, long-term approaches that integrate adaptation into regional planning, enhance access to adaptive technologies, and support community organizations and education. To enhance the effectiveness of government assistance, participatory needs assessments should allow fishermen to identify specific support requirements, while digital tracking platforms can improve the transparency and efficiency of aid distribution. Furthermore, establishing village-based "Climate Information Posts" can provide real-time weather and fishing data, particularly in areas with poor internet access. Public funding could also be allocated to subsidize smartphones or mobile data packages for low-income fishermen, along with targeted digital literacy training to empower them in utilizing these technologies effectively.

The study also notes that adaptation burdens are unevenly distributed, often marginalizing women and children, underscoring the need for inclusive participation in decision-making. These findings align with theories of human adaptation that stress the interaction of individual and social factors. Additionally, combining local ecological knowledge with scientific data and leveraging strong social networks further strengthens community resilience to climate impacts (Coulthard et al., 2011).

This study has notable limitations, including its focus on just four coastal villages in North Lombok Regency, which may not reflect the diversity of small-scale fishing communities in Indonesia. Additionally, data collection occurred during a specific seasonal period, potentially affecting respondents' recall of climate impacts and adaptation strategies. These limitations suggest the need for future research that includes a broader geographic scope and considers various seasonal contexts for a more comprehensive understanding.

4. Conclusions

This study examined the impacts of climate change on small-scale fishermen households in North Lombok Regency. The AHP analysis identified diversification of fishing gear and household income as priority adaptation strategies for small-scale fishermen households facing climate change. Other strategies include government assistance, technology use, social network strengthening, and environmental restoration. Adaptability is strongly influenced by social capital, savings, and access to information, highlighting the importance of institutional support. Policy-

wise, a systemic and long-term approach is needed, embedding adaptation into regional planning, improving access to adaptive technologies, and supporting community organizations and education. The study also emphasizes inclusive participation, noting that women and children are often marginalized in decision-making despite their critical roles.

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