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Sustainability of Community Social Resilience in Flood Disaster Mitigation and Adaptation for Global Flood-Prone Communities: Evidence from Kampar Regency, Riau, Indonesia

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ABSTRACT

As climate change intensifies and environmental degradation worsens, flooding has transformed from a seasonal event into a persistent and escalating threat. Rural areas are particularly vulnerable due to their limited adaptive capacity and fragile social structures. The increasing frequency and severity of floods underscore the urgent need for both structural reforms and the strengthening of community-based social systems. However, existing studies have not adequately addressed the research gaps, especially concerning how specific components of community social resilience contribute to effective flood disaster management in rural contexts. This study aims to fill that gap by analyzing the role of sustainable community social resilience in managing and adapting to flood disasters in Kampar Regency. The research employs the Rapid Appraisal for Resilience method and analyzes data using Multidimensional Scaling (MDS). It focuses on four key dimensions: social, education, health, and economics. Primary data were collected through interviews with 105 purposively selected respondents from flood-affected communities across 22 subdistricts in Kampar Regency. The results of the multidimensional sustainability index indicate an overall score of 49.06, categorizing the area as "less sustainable." The dimension-specific scores were as follows: economic (50.29), social (46.08), health (50.10), and education (49.76). These results reveal uneven levels of community resilience, with economic and health dimensions showing slightly better outcomes than others. Tailored interventions addressing dimension-specific weaknesses are essential. Strengthening these localized aspects supports long-term strategies for disaster risk reduction and climate adaptation. This study underscores the importance of incorporating multidimensional assessments into local development planning to build resilience in flood-prone communities.

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1. Introduction

According to data from the National Disaster Management Agency (BNPB, 2023), floods are among the most common natural disasters in Indonesia. Floods account for more than 30% of the total disaster occurrences each year, affecting a wide range of areas from coastal zones to inland regions (BNPB, 2023). The increase in flood events cannot be separated from the dynamics of global climate change, which has led to increasingly erratic and extreme rainfall patterns (IPCC, 2023). In contrast, environmental degradation caused by land use change, deforestation, and unsustainable development has accelerated surface runoff and reduced the capacity of the ecosystem to absorb excess water (Yulianto et al., 2022; Sajikumar and Remya, 2014). In addition to ecological factors, social aspects, such as rapid and uncontrolled population growth in disaster-prone areas, have also increased community vulnerability to floods (Emam et al., 2016). Settlements that develop along riverbanks or in lowland areas without adequate spatial planning further complicate disaster risk, making them more complex and multidimensional. Therefore, floods today are not merely viewed as natural phenomena but also as part of a broader development crisis that demands a holistic community-based disaster management approach that incorporates social–ecological sustainability (Fatmawati et al., 2024). Structural approaches, including the construction of embankments, flood canals, and river normalization, have dominated disaster management efforts in Indonesia. Although these physical interventions offer immediate protection, they often fail to build long-term community resilience, especially despite recurrent and increasingly intense floods (Fatmawati et al., 2024). Infrastructure failures during extreme events underscore the need for nonstructural strategies that place communities at the center of disaster risk reduction. Non-structural approaches emphasize strengthening social capacity, promoting disaster education, and empowering local communities to anticipate, respond, and recover from disasters independently and sustainably (Zhao et al., 2025). In their influential work, At Risk: Natural Hazards,

People's Vulnerability, and Disasters, they define social resilience as the ability of a community to survive and thrive amidst uncertainty and hazards, drawing upon social capital, collective participation, and local knowledge. Several studies have demonstrated that community resilience to flooding is significantly influenced by the strength of social capital, including solidarity among residents, trust in regional institutions, and the capacity of community organizations (Darab et al., 2021).

Recent empirical research has consistently underscored the pivotal role of social capital in shaping flood resilience across diverse contexts (Chen et al., 2024). A comparative study was conducted in seven flood-prone communities in Nanjing, China, revealing that social cohesion and collective efficacy were the strongest predictors of community resilience, notably through factor and regression analyses. Expanding this to cross-country dynamics, a comparison of flood resilience in Japan, Indonesia, and Taiwan demonstrated that eco-DRR strategies supported by strong community networks significantly enhance the capacity to withstand floods. Complementing these (Zhang et al., 2024). This study highlighted how robust health systems and socioeconomic resilience interact within Indonesian flood-exposed communities to mitigate climate impacts. In addition (Liu & Mostafavi, 2025). introduced a network-centric model, emphasizing that dense and trust-based social networks accelerate post-flood recovery in various communities. While these studies offer valuable insights into single or dual dimensions of resilience, such as social capital, Eco-DRR, health systems, and network ties, they remain fragmented and often focus on urban settings or specific sectors. They lack a holistic, quantitative, and multidimensional assessment of social resilience sustainability that integrates the social, economic, educational, and health dimensions in rural flood-prone areas. This identifies a clear research gap in empirically measuring and understanding sustained social resilience across multiple dimensions in rural contexts, such as Kampar Regency.

Although the concept of social resilience has been widely discussed, there remains a lack of studies that assess the sustainability of social resilience using a multidimensional approach, particularly in rural flood-prone areas, such as Kampar Regency. Most existing studies have focused on a single aspect, such as economic or infrastructure factors. The novelty of this study lies in its application of the Rapid Appraisal for Fisheries (Rapfish) method, which is typically used in fisheries and marine contexts, to evaluate community social resilience to flood disasters across four key dimensions: social, economic, education, and health, using MDS. Analysis (Chaliluddin et al., 2023). This approach yields quantifiable sustainability indices, enabling more targeted and context-specific policy recommendations rather than relying on generalized one-size-fits-all strategies. Therefore, this research not only contributes to the academic discourse on social resilience but also offers practical insights for disaster risk reduction and climate adaptation planning in vulnerable communities.

In response to this critical research gap, the present study aimed to assess the sustainability of community social resilience to flood disasters at the sub-district level in flood-prone areas. Recognizing the complex interconnections between social, economic, educational, and health dimensions, this study addresses the central question: "How sustainable is community social resilience to flood disasters, and which sensitive attributes most influence this resilience?" Specifically, it examines the roles of community participation, social cohesion, and trust in local institutions in shaping social resilience, income levels, livelihood diversification, and financial access in determining economic resilience, educational attainment, disaster-related knowledge in enhancing preparedness, and access to healthcare and the quality of sanitation in supporting health resilience. By addressing these dimensions holistically, the study not only contributes to academic discourse but also delivers urgently needed evidence-based insights for policymakers. Strengthening social resilience must be treated as an immediate priority, particularly in rural areas where vulnerabilities are multidimensional, and the capacity to recover from recurrent floods remains critically low. Without a shift toward community-empowered and context-specific strategies, flood-prone populations will continue to face escalating risks despite climate change and developmental pressures.

2. Method

This study employed a descriptive quantitative method, in which numerical data were collected through a structured questionnaire based on indicators derived from the studied variables. Primary data were obtained from public perceptions of communities living in the flood-prone areas of the Kampar Regency. These perceptions encompass their views on preparedness, adaptive capacity, and experiences in dealing with floods as well as their assessments of social, economic, educational, and health support in their respective areas. The primary research instrument was a closed-ended questionnaire developed around four key dimensions of sustainable development: social, economic, educational, and health. Each attribute was assessed using a 4-point Likert scale to measure the level of sustainability. The sampling technique

employed was purposive sampling, where respondents were selected based on the following specific criteria: they resided in flood-prone areas in Kampar Regency, had experienced flooding within the last three years, and were at least 18 years old. A total of 105 respondents were selected from the priority villages identified by the local Disaster Management Agency (BNPB, 2023). Most respondents (around 67%) were heads of household. At the same time, the rest were other adult household members, such as spouses or grown children, who were considered knowledgeable about the household's social and economic conditions. The majority of the respondents were between 30 and 55 years old, with senior high school being the most common level of education. The gender distribution was relatively balanced between the male and female respondents. Furthermore, most had lived in their respective areas for more than ten years, providing them with firsthand experiences of recurring flood events and a deep understanding of the community's resilience dynamics. Validity and reliability tests were conducted before the data collection to ensure the quality of the research instrument. Validity was assessed using an item-total correlation to confirm that each questionnaire item accurately represented the intended attribute. Reliability was assessed using Cronbach's alpha, and all dimensions yielded values above 0.70, indicating strong internal consistency and suitability for further statistical analysis.

The analysis was carried out using MDS with the Rap-Resilience (Rapid Appraisal of Resilience) approach, which is a modification of Rapfish analysis developed by the University of British Columbia, Canada (Tony J. Pitcher & Preikshot, 2001). MDS analysis, as developed in the Rap Resilience software, was used to assess each measurable indicator. MDS is a statistical technique that transforms multidimensional data into lower-dimensional data. In this study, attribute scores from the questionnaire were processed in Rap-Resilience software to generate sustainability indices for each dimension and overall. The model fit was evaluated using the stress and R-squared values. The leverage analysis identified the most sensitive attributes, and a Monte Carlo simulation was used to test the robustness of the results. The dimensions used in rap-Resilience are based on four aspects of sustainable development: health, economy, education, and social (Tony J. Pitcher & Preikshot, 2001). The sustainability index values used as reference in this research are shown in Table 1.

Table 1. Sustainability Index Values

No	Index Value Range	Category	Description
1	0,00 – 25 00	Poor	Not sustainable
2	25, 01 – 50, 00	Low	Less sustainable
3	50, 01 – 75,00	Moderate	Moderately sustainable
4	75, 01 – 100, 00	Good	sustainable

Source: (Pitcher et al., 2013)

Each attribute across the four dimensions was assessed using questionnaire data and processed using Rap-Resilience software to determine its position in a multidimensional space. The analysis produced a sustainability index, along with a stress value and R^2, to evaluate the accuracy of data mapping. The sustainability index categorizes community resilience into four levels: unsustainable, less-sustainable, moderately sustainable, and sustainable.

Leverage analysis was also conducted to identify the most sensitive attributes in each dimension based on the highest root mean square (RMS**)** values. These key attributes were prioritized to improve community resilience. This approach provides a comprehensive overview and generates context-specific data-driven policy recommendations. The resulting sustainability index scores were scaled from 0 to 100 and classified into four categories: unsustainable (0.00–25.00), less sustainable (25.01–50.00), moderately sustainable (50.01–75.00), and sustainable (75.01–100.00). To validate the MDS model, a Monte Carlo simulation with 25 iterations was conducted to test the robustness of the analysis. Additionally, leverage analysis was performed to identify the most sensitive attributes that influence sustainability scores. The analysis focused on four main parameters: the social dimension included indicators such as comprehensive evacuation, shelter, volunteers, participation in social activities, and a disaster-aware community; the economic dimension covered household income, access to economic resources, and government financing subsidy; the education dimension covered teaching and learning conditions during floods, post-flood schools, school preparedness for floods, Internet conditions, and access education programs; and the health dimension evaluated access to healthcare services, sanitation conditions, and operational and healthcare accessibility. These dimensions are selected to reflect the comprehensive relationship between sustainable development and social resilience in the context of recurrent flood disasters.

3. Results and discussion

3.1 Analysis of the sustainability index and the status of social resilience to flooding in kampar regency

The sustainability assessment was conducted using the MDS method with the aid of the RAP-Resilience software, utilizing primary data obtained through interviews with residents of Kampar Regency. The results indicate that the sustainability index of community resilience in flood disaster adaptation and mitigation is 49.06 on a scale of 0 to 100, which is categorized as "Less Sustainable." Each dimension comprises a set of attributes that serve as indicators for evaluating the sustainability of community resilience in response to and mitigating flood disasters in the Kampar Regency.

3.1.1. Social dimension

Social resilience is a key element in addressing flood disasters, particularly in rural areas, such as the Kampar Regency. Studies have highlighted that social capital, encompassing networks, trust, and norms of collective participation, plays a pivotal role in enhancing community adaptation to floods (Zhao et al., 2025). In Kampar, strong communal bonds are rooted in Islamic customs and values, encapsulated in the philosophy *"Adat basandi syarak, syarak basandi Kitabullah"*, which reinforces collective norms and social trust. Initiatives such as the Resilient Village Program in Buluh Cina and community behavior in addressing flood-related health impacts in Lubuk Siam illustrate the potential of local strengths (Hermon et al., 2024). However, no empirical studies have specifically examined social resilience within Kampar's local sociocultural framework. Informal social forces, including the influence of community leaders and kinship mechanisms, offer practical avenues for community-based disaster education and awareness yet remain underutilized in formal disaster policies. Limited community involvement in policy planning and the absence of robust communication forums with the government indicate socio-structural gaps. Strengthening social resilience in Kampar requires empowerment programs that connect local strengths to institutional systems (Sihaini & Hermon, 2025).

There is an urgent need for focused research on social resilience in Kampar to identify existing social capital and to design empowerment strategies that connect local capacities with institutional support. Such efforts would strengthen the adaptive capacity and support sustainable context-sensitive flood mitigation. A thorough understanding of a community's social conditions is crucial for developing targeted strategies. The results of the analysis are shown in Figure 1.

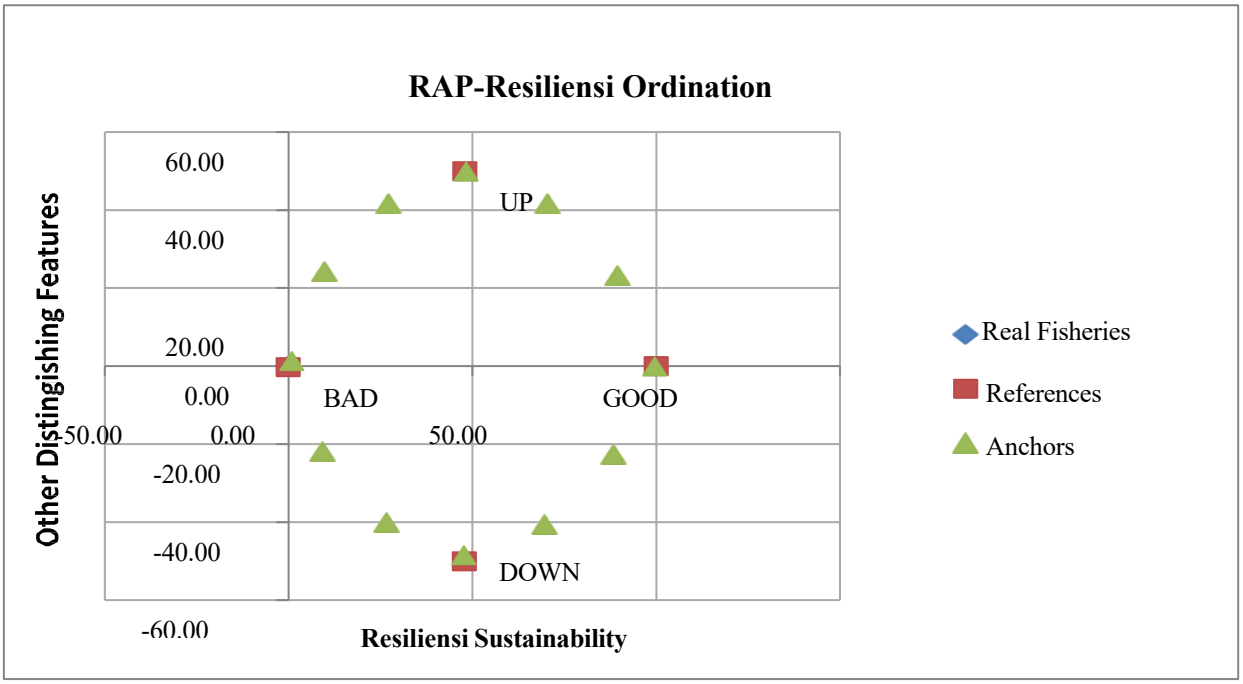

Figure 1. Sustainability Index Value of Social Dimension Resilience In Flood Disaster

Based on the analysis results, as illustrated in Figure 1, the point's position is below the midpoint (46.08), which indicates that the community's level of resilience is still categorized as "less sustainable." This condition, shown in Figure 1, reflects existing vulnerabilities in the social dimension.

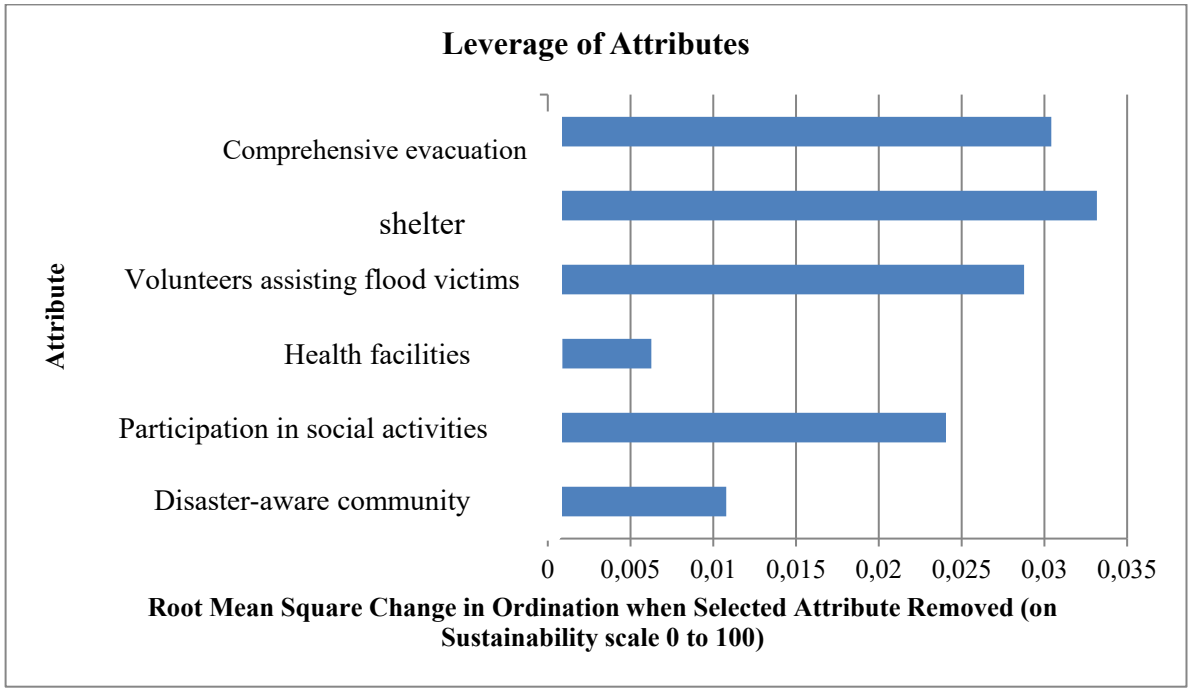

Figure 2. Sensitive Attributes Influencing the Sustainability of Social Resilience

The analysis of the leverage of attributes reveals that Shelter, Comprehensive Evacuation, and Volunteers Assisting Flood Victims make the most significant contribution to changes in the ordination position of community social resilience. This finding is consistent with the social capital theory. As shown in Figure 2, these attributes occupy the highest leverage values and, therefore, act as key factors in strengthening community social resilience. Recent studies suggest that in the context of disasters, social capital, particularly the mechanisms of bonding, bridging, and linking, provides a critical foundation for enhancing community response, recovery, and adaptation (Zhao et al., 2025). The attributes of shelter and comprehensive evacuation reflect structural and institutional capital within the framework of resilience capacity-building (Norris et al., 2008). The presence of volunteers illustrates the relational social capital that strengthens networks among individuals and institutions, following international standards such as ISO 22319 on spontaneous volunteer planning. Empirical findings from Nanjing (2024) further reinforce the notion that social cohesion and collective efficacy are key indicators of community success in addressing flood disasters (Emam et al., 2016). Furthermore, participation in social activities demonstrates significant leverage (-0.027), highlighting the importance of bonding social capital. Putnam (2000) argues that trust and solidarity within a community increase when individuals actively engage in networks and social interactions, which in turn accelerates post-disaster recovery. This finding is supported by recent research in Ghana, which indicates that collective social capital is a stronger predictor of community resilience to floods than is individual social capital (Savari et al., 2024). Conversely, the attributes' Health and Disaster-aware community show low leverage, suggesting that while these aspects are essential as cognitive and normative capital, they are insufficient to shift resilience positions without the support of substantial social and structural capital. This aligns with the concept of compensatory resilience, in which promotive factors such as social capital can offset weaknesses in other dimensions (Norris et al., 2008).

Overall, these findings are consistent with the principles of compensatory resilience models, in which social capital, volunteer networks, and shelter infrastructure serve as key promotive factors that compensate for community vulnerability during disasters. A study in Nanjing (2024) reinforced this finding by demonstrating that social cohesion and collective efficacy are key factors for enhancing community flood resilience (Savari et al., 2024). Similarly, research in rural Iran has revealed that social capital accounts for 68% of the variance in rural flood resilience (Gyawali et al., 2020).

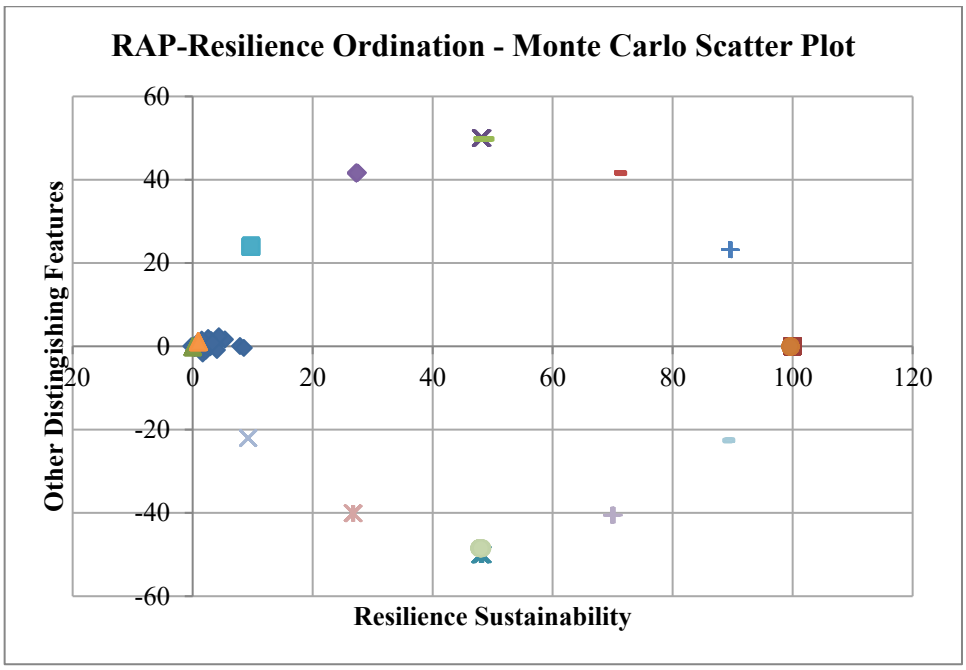

Figure 3. RAP-Resilience Ordination Social Dimension - Monte Carlo

Figure 3 shows the Monte Carlo Scatter Plot, which illustrates the simulation points used to test the robustness of the sustainability results. The X-axis (Fisheries Sustainability: 0–120) and Y-axis (Other Distinguishing Features: <60 → 60) show most points clustered at lower X-axis values, indicating low socio-ecological resilience and a limited adaptive potential. A few points at higher values indicate minor improvements. This pattern highlights the importance of strengthening social and institutional capital through adequate shelters, effective evacuation systems, and empowering volunteers to enhance their resilience against future disasters. These patterns closely align with findings from Nanjing, China, which identified social cohesion and collective efficacy as the most influential dimensions of social capital driving community resilience in flood-prone communities. Even when economic indicators improve, communities lacking these social strengths struggle to adapt effectively and achieve sustained resilience (Chen et al., 2024). Moreover, it has been demonstrated that communities leveraging digital tools such as early warning systems, social media, and satellite imaging can enhance social capital and disaster preparedness. Their Monte Carlo-based evaluation revealed that communities with higher social capital produce broader resilience distributions, indicating greater and more reliable adaptive capacity than narrowly dispersed, constrained communities (Piseddu et al., 2024). In Kampar, the clustering of low-value simulation points reflects weak institutional trust, limited participation, and poor disaster literacy, aligning with the global and regional findings. Resilience strategies should extend beyond infrastructure, integrating social and cultural interventions, such as community-led training, revitalized neighborhood networks, and transparent local communication channels. While infrastructure is important, the core of long-term resilience lies in substantial social capital, including trust, cohesion, and community responsiveness, making it foundational for sustainable disaster risk adaptation.

3.1.2. Education dimension

The RAPFISH ordination plot incorporating the educational dimension positioned the community's educational sustainability near the "BAD" reference point, indicating an underperforming educational component within the broader socio-ecological system. These findings indicate low levels of disaster literacy, limited integration of disaster and climate risk topics into school curricula, and insufficient informal educational support. According to resilience theory, education serves as critical cognitive capital, strengthening both adaptive and transformative capacities in communities (Norris et al., 2008). Empirical evidence confirming these findings shows that integrating disaster risk reduction (DRR) into school curricula significantly enhances resilience by increasing awareness and preparedness among students and their families (Alshammari et al., 2023). However, local research demonstrating the effectiveness of school-based disaster education in reducing vulnerability (Torani et al., 2019) contradicts the low educational sustainability scores found in Kampar.

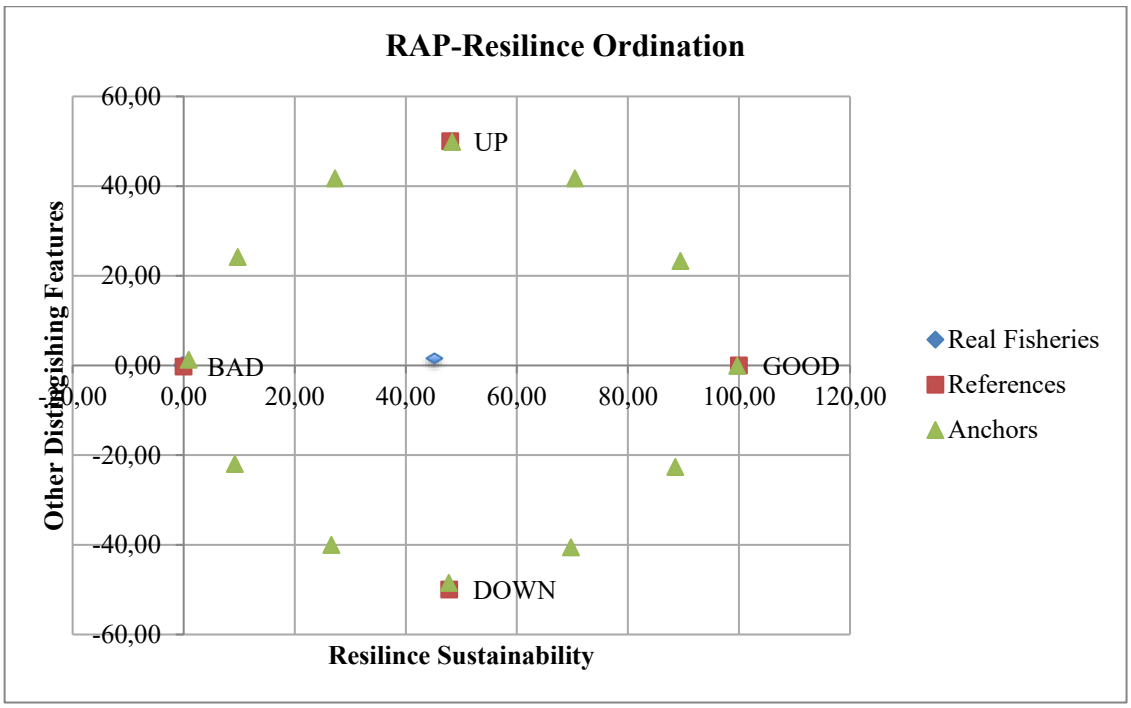

Figure 4. Sustainability Index Value of The Education Dimension Resilience In The Flood Disaster

Figure 4 illustrates that the point's position is below the midpoint (49.76), indicating that the community's level of resilience is still categorized as "less sustainable." This reflects vulnerabilities in the education dimension by showing how its scores fall below the sustainability threshold compared to other dimensions, highlighting its contribution to the community's lower resilience level.

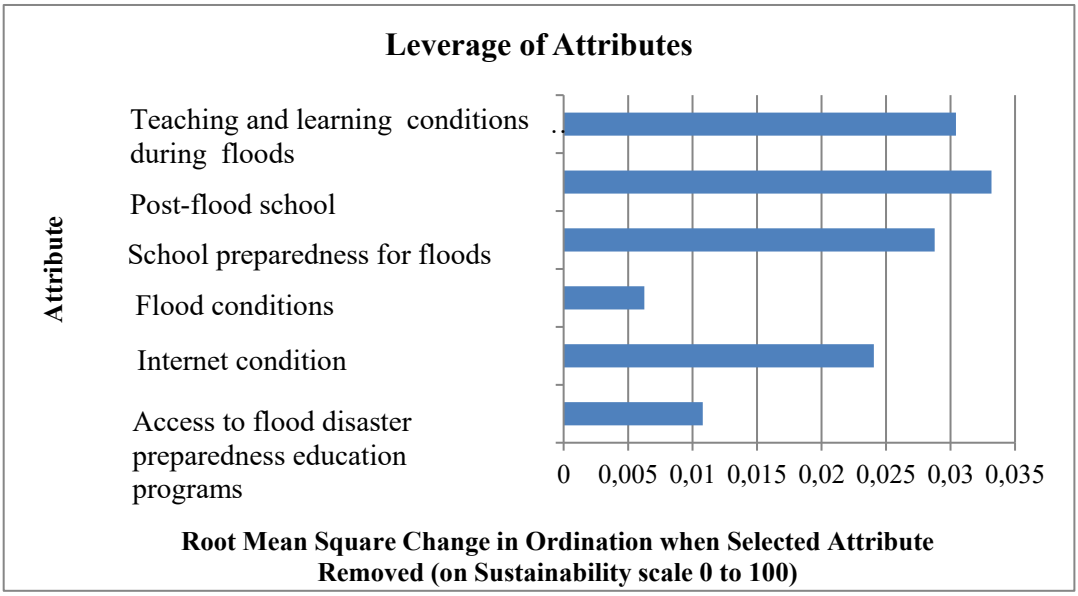

Figure 5. Sensitive Attributes Influencing the Sustainability of Education Resilience

Figure 5 illustrates that the three main attributes with the most significant influence on the education dimension are teaching and learning conditions during disasters, availability of schools after floods, and school preparedness for disasters. The attributes of teaching and learning conditions showed the highest leverage, highlighting the importance of maintaining educational continuity during crises. The availability of post-disaster schools serves as a recovery hub for affected students, while school preparedness helps minimize potential losses. Additionally, flood disaster awareness programs contribute significantly to building community capacity. Meanwhile, Internet accessibility and disaster awareness have lower leverage

but remain essential for supporting information access and risk literacy. These findings underscore the need to prioritize educational continuity and school preparedness in disaster mitigation strategies.

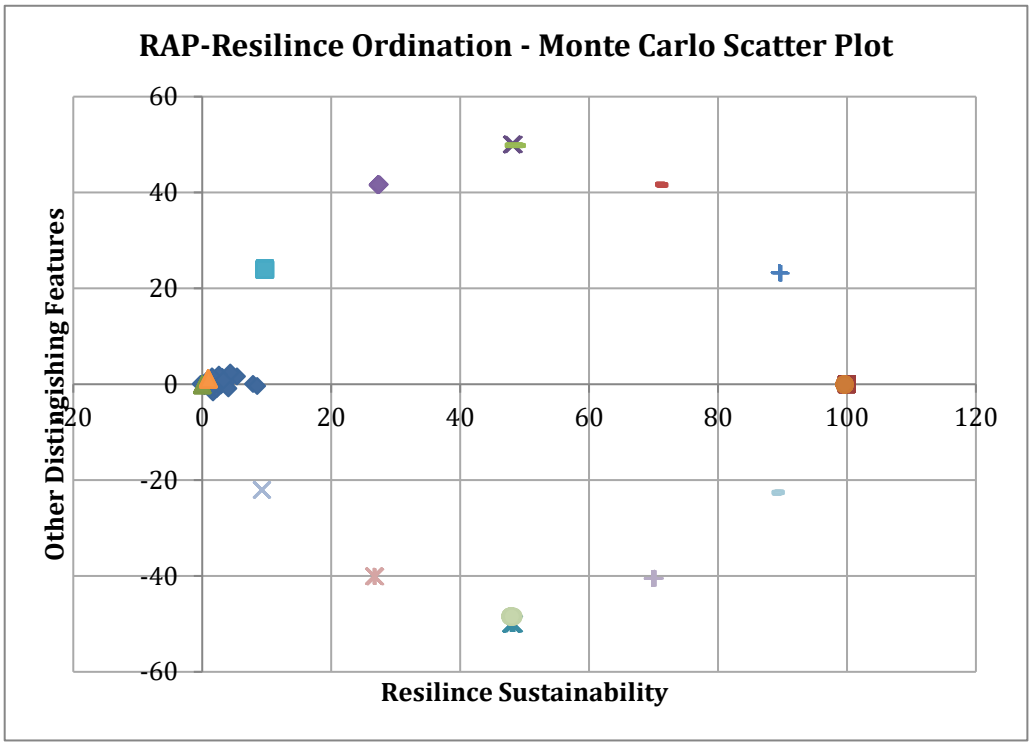

Figure 6. RAP-Resilience Ordination Education Dimension - Monte Carlo

Figure 6 illustrates the Monte Carlo scatter plot of educational resilience scores,The RAPFISH analysis, supported by Monte Carlo simulations and revealed considerable variability in the sustainability of educational resilience in the Kampar Regency. Most Monte Carlo scenarios clustered within the range of 0–200, indicating that the resilience level was categorized as low. However, the wide dispersion of points, including extreme values (>100 and <0), highlights the significant uncertainty in the ordination results. This suggests that the education system in Kampar remains highly vulnerable to disaster disruptions and sensitive to changes in key attributes. Figure 6 illustrates this by displaying the Monte Carlo scatter plot of the educational resilience scores, clearly showing the clustering of most scenarios within the low-sustainability zone and the presence of outliers beyond the threshold, which underscores the uncertainty and vulnerability of the education dimension.

High-leverage attributes, such as school preparedness for disasters, availability of post-disaster educational facilities, and continuity of teaching and learning processes, are the main factors influencing the instability of sustainability scores. Schools have been emphasized as critical centers for children's physical and psychosocial recovery after disasters (Alshammari et al., 2023). Similarly, the Global Partnership for Education (2024) emphasized the importance of adopting proactive and responsive strategies to enhance educational resilience (Kelcey, J et.al., 2024). To address these challenges in Kampar, strategic interventions are necessary, including disaster preparedness training for teachers and students, rapid recovery of educational facilities, and development of emergency education platforms that utilize digital technology. These measures are expected to stabilize sustainability scores in Monte Carlo simulations and strengthen the capacity of the educational system to withstand future disasters (Sittadewi et al., 2025).

3.1.3 Health dimension

The Global Partnership for Education (2024) emphasizes that access to disaster-responsive health services is a critical component in strengthening the overall resilience of education systems (Kelcey, J et.al., 2024).

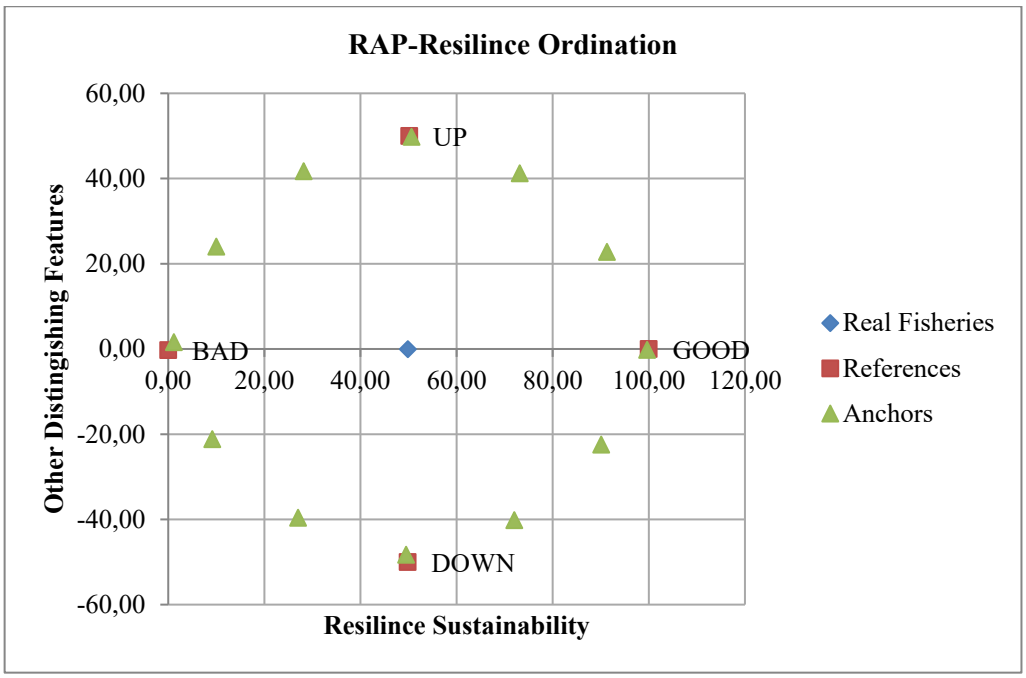

Figure 7. Sustainability Index Value of the Health Dimension: Resilience in the Flood Disaster

Figure 7 explains the RAPFISH ordination results for the health dimension, which shows a distribution of sustainability scores represented by points for Real Fisheries, References, and anchors. The Real Fisheries point was positioned within the score range of 50–60, indicating a Moderately Sustainable rating of 50, with 11 points in the health dimension. Reference points, such as BAD (with scores near 0) and GOOD (with scores close to 100), serve as benchmarks for interpreting the results. The distribution of anchors across all quadrants, including UP and DOWN, reflects the considerable variability among the attributes within this health dimension.

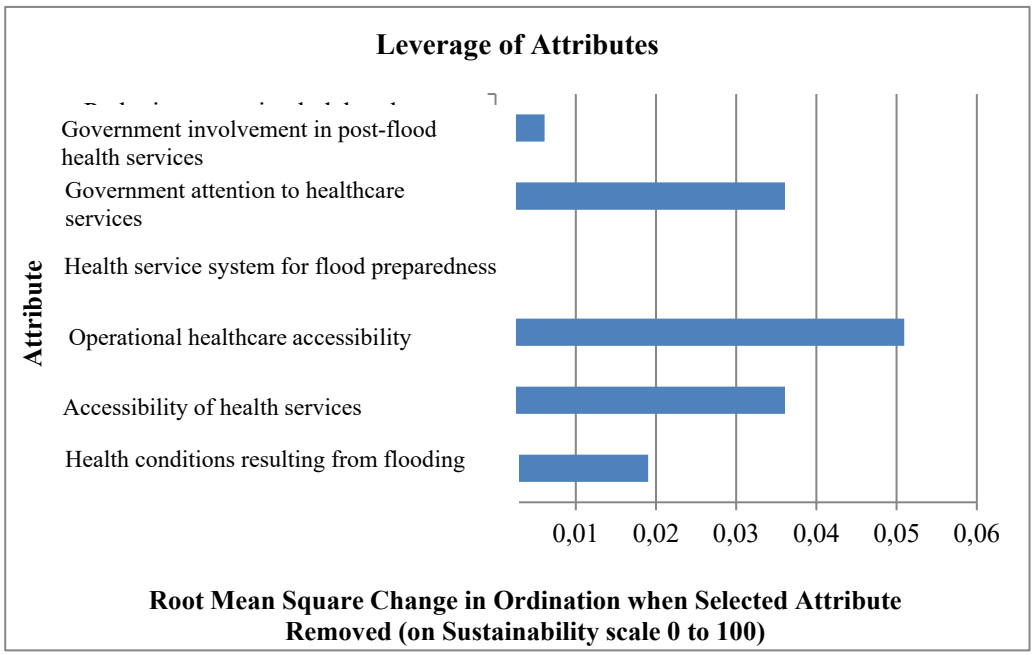

Figure 8. Sensitive Attributes Influencing the Sustainability of Health Resilience

These findings suggest that health resilience in Kampar in the context of flood disasters is in a moderate state, necessitating targeted improvements in health service accessibility, school-based health programs, and post-disaster recovery systems. This finding aligns with previous studies, which have shown that community resilience in flood-prone areas is often hindered by inadequate health infrastructure and a lack of integration between health and education systems. Strengthening public health systems, particularly in schools, can reduce vulnerability and enhance adaptive capacity, ultimately ensuring continuity of education during

disasters. Similarly, the Global Partnership for Education (2024) emphasizes that access to disaster-responsive health services is a key component in building the overall resilience of education systems (Kelcey, J et.al., 2024).

Based on the leverage analysis in the health dimension Figure 8, the attribute "Operational healthcare accessibility" shows the highest leverage (0.052), indicating its critical role in ensuring the continuity of healthcare services during disasters. This finding highlights the importance of ensuring optimal access to healthcare to maintain health services during emergencies. Government attention to healthcare services ranks second (0.035), highlighting the importance of government support in providing general healthcare services for disaster mitigation and post-disaster recovery efforts. The attribute" accessibility of health services' also exhibited a significant influence (0.033), emphasizing the necessity of ensuring accessible healthcare for affected communities. Meanwhile, health conditions resulting from flooding (0.018) reflect the health impacts on communities that influence the overall system sustainability. Government involvement in post-flood health services shows a lower leverage (0.007), yet it remains relevant in maintaining health service continuity after disasters. The health service system for flood preparedness has the lowest leverage (0.001), indicating its relatively limited influence, although it still contributes to pre-disaster preparedness (Kelcey, J et.al., 2024). These results align with those of Pacheco et al. (2022), who highlighted that rapid access to healthcare has a significant impact on the recovery process of education and child well-being following disasters (Pacheco et al., 2022) Similarly. The Global Partnership for Education (2024) emphasized that educational resilience depends significantly on the availability of disaster-responsive health services, which protect students and teachers from the secondary impacts of disasters. Sittadewi et al. (2025) identified emergency healthcare accessibility as a key indicator of social resilience in disaster-prone regions across Southeast Asia (Sittadewi et al., 2025).

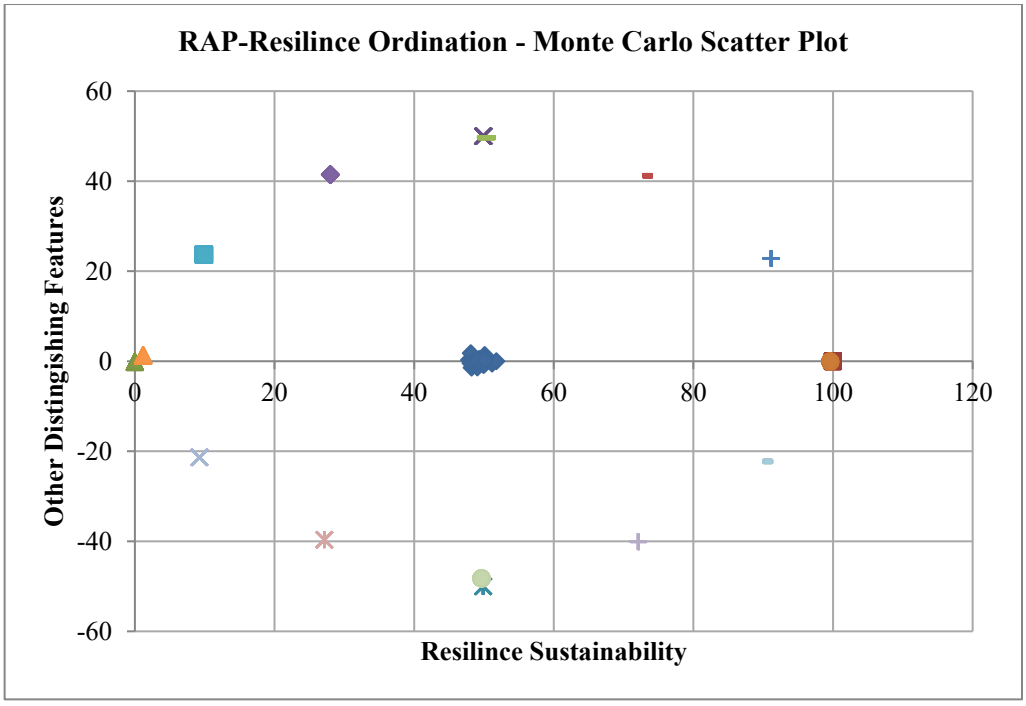

Figure 9. RAP-Resilience Ordination Health Dimension - Monte Carlo

The Monte Carlo scatter plot in Figure 9 from the RAPFISH ordination revealed the uncertainty and stability of the sustainability assessment of the health dimension. The clustering of real data points around mid-range scores (<50–60) indicates a moderate level of health resilience in the Kampar Regency. This indicates that while some resilience exists, the system remains vulnerable to disaster stressors. The wide dispersion of Monte Carlo points in every quadrant highlights the variability caused by perturbing the key health-related attributes. Points close to the BAD reference (<0) signal critical vulnerabilities, whereas those near the GOOD reference (<100) indicate the potential for resilience improvements if attributes such as operational healthcare accessibility and government attention to healthcare are strengthened. This pattern aligns with findings from the primary health care (PHC) disaster preparedness framework, which emphasizes the need for system-wide readiness, including service delivery, workforce, and community linkages in disaster contexts (Kim et al., 2016). Moreover, studies on hospital resilience have noted that organizational

adaptability and infrastructure robustness are key to ensuring continuity during crises. These insights reinforce the importance of operational healthcare access and government support as essential contributors to system resilience (Talab et al., 2024).

3.1.4 Economic dimension

Emphasizing economic sustainability in disaster-prone areas strongly depends on access to microfinancing and cost efficiency within local business sectors (Madinatunnisa et al., 2025). Innovations in supply chain integration significantly enhance the economic resilience of coastal communities to shocks.

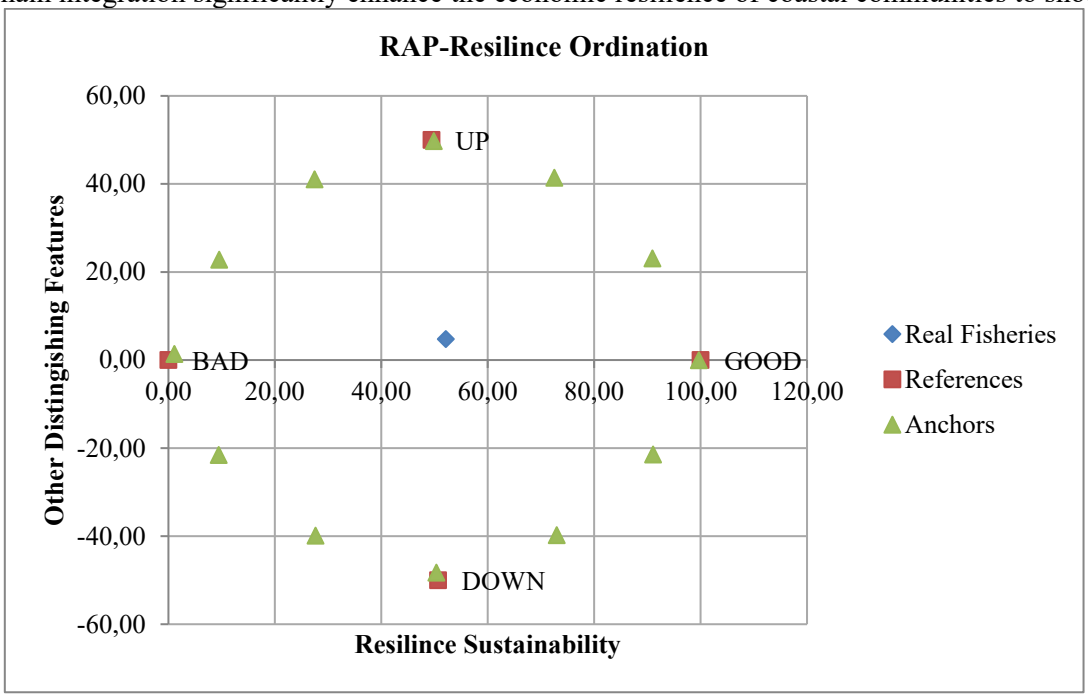

Figure 10. Sustainability index value of the economic dimension resilience in the flood disaster

Figure 10 explains the RAPFISH ordination results for the economic dimension, which show a sustainability score of approximately 55 on the Fisheries Sustainability axis. This position is the economic dimension of Kampar Regency in the category of "moderately sustainable," indicating that while several economic aspects support community resilience, there are still notable vulnerabilities that require attention.

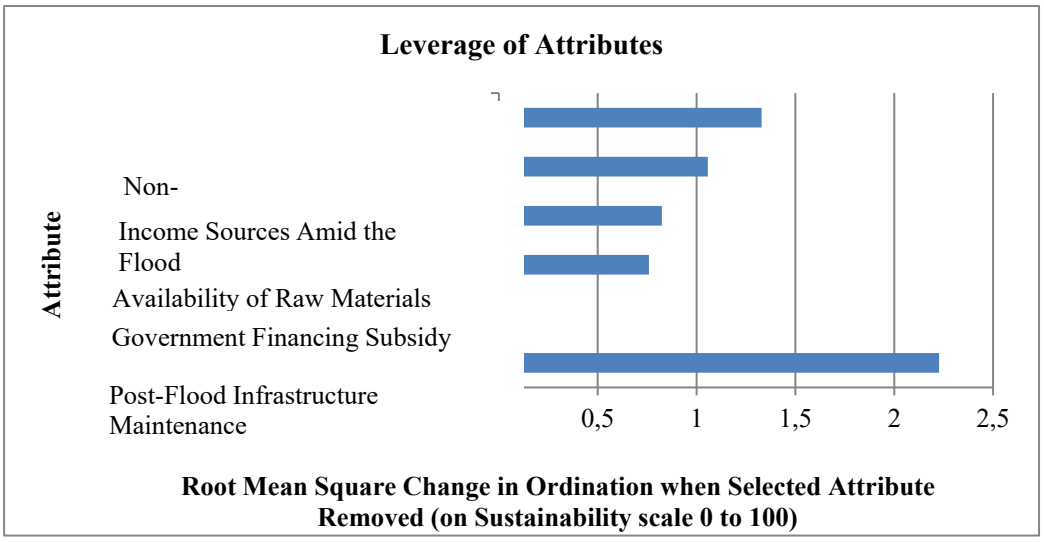

Figure 11. Sensitive Attributes Influencing the Sustainability of Economic Resilience

These findings are consistent with previous research, indicating that limited financial resources, infrastructure damage, and market disruptions often hinder economic resilience in flood-prone areas. Strengthening access to capital, promoting income diversification, and investing in disaster-resilient infrastructure are critical strategies for enhancing the economic sustainability of disaster-affected communities. Similar patterns have been observed in other regions, where integrated economic planning and risk reduction measures significantly improved the recovery speed and reduced long-term vulnerabilities.

Figure 11 illustrates the economic dimension analysis, revealing that flood resilience in the Kampar Regency is significantly influenced by economic capacity, particularly in restoring livelihoods. This figure 12 highlights how the economic capacity of households contributes to recovery speed and overall community resilience after floods.. The attribute leverage graph identifies post-flood infrastructure maintenance as having the highest leverage, emphasizing the role of resilient infrastructure in economic recovery (Azhar, 2022). Consistent with previous studies, infrastructure rehabilitation directly supports faster recovery and improved market access. Post-flood income sources also play a significant role, with access to alternative livelihoods, such as community-based microenterprises, serving as a critical buffer (Yaron & Wilson, 2020). The RAPFISH results reveal challenges, including high input costs and limited financial capital, aligning with evidence that a lack of banking access hampers business restoration. Proactive strategies that integrate microfinance and livelihood skill training are recommended. Livelihood diversification, especially beyond agriculture, further strengthens resilience, as confirmed by findings in Malaysia, highlighting cross-sector collaboration to improve economic resources and supply chain efficiency (International Bank for Reconstruction and Development, 2024). Overall, Kampar's economic resilience is moderately sustainable, with the need to expand financial access, diversify income, rehabilitate infrastructure, and empower community-based initiatives for long-term flood resilience.

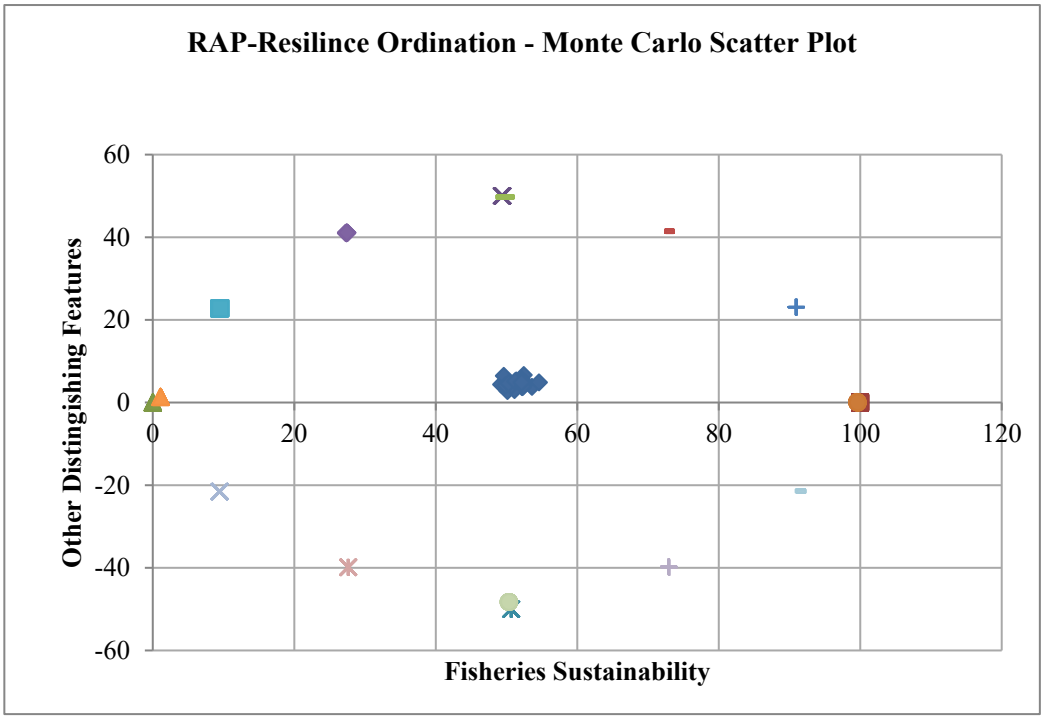

Figure 12. RAP-Resilience Ordination Economic Dimension - Monte Carlo

Figure 12 shows the Monte Carlo scatter plot in the RAPFISH ordination, which illustrates the variability and reliability of the economic sustainability assessment in the Kampar Regency, where the cluster of Real Fisheries (represented by blue diamonds) concentrated around mid-range scores (50–60) indicates that the community's economic resilience is in the moderately sustainable category. Although the community has a moderate adaptive capacity, significant vulnerabilities remain, particularly in the post-flood economic recovery phase. The reference points BAD (near 0) and GOOD (near 100) serve as benchmarks, highlighting a substantial gap between the current situation and the ideal state of economic sustainability. Figure 13 further explains this by displaying the distribution of leverage values for key economic attributes, showing which factors most strongly influence the ordination results and contribute to the observed gap between current and ideal economic sustainability.

The spread of anchors across all quadrants reflects the presence of both the supporting and constraining factors. Anchors in the upper quadrants indicate positive contributions such as post-flood livelihood recovery programs and the development of community-based microenterprises. In contrast, anchors in the lower quadrants reflect challenges, such as high production input costs and limited access to financial capital. It has been highlighted that economic diversification and community-based financing initiatives are key to sustaining livelihoods in flood-prone areas (Ivanova & Büchs, 2022). This analysis underscores the need for an economic recovery strategy in the Kampar Regency, emphasizing the importance of livelihood diversification, improved access to microfinance, and enhanced supply chain efficiency. Such approaches are anticipated to strengthen a community's capacity for sustainable resilience against flood impacts.

3.2 Sustainability index values of the four dimensions

The MDS analysis yielded index values and sustainability status for the resilience, adaptation, and mitigation capacities of the Kampar community in response to flood disasters. The sustainability status and index values reflect the current level of sustainability in the Kampar Regency, both from a multidimensional perspective (a combination of all four dimensions) and from each dimension. Based on these five dimensions, as illustrated in Figure 13.

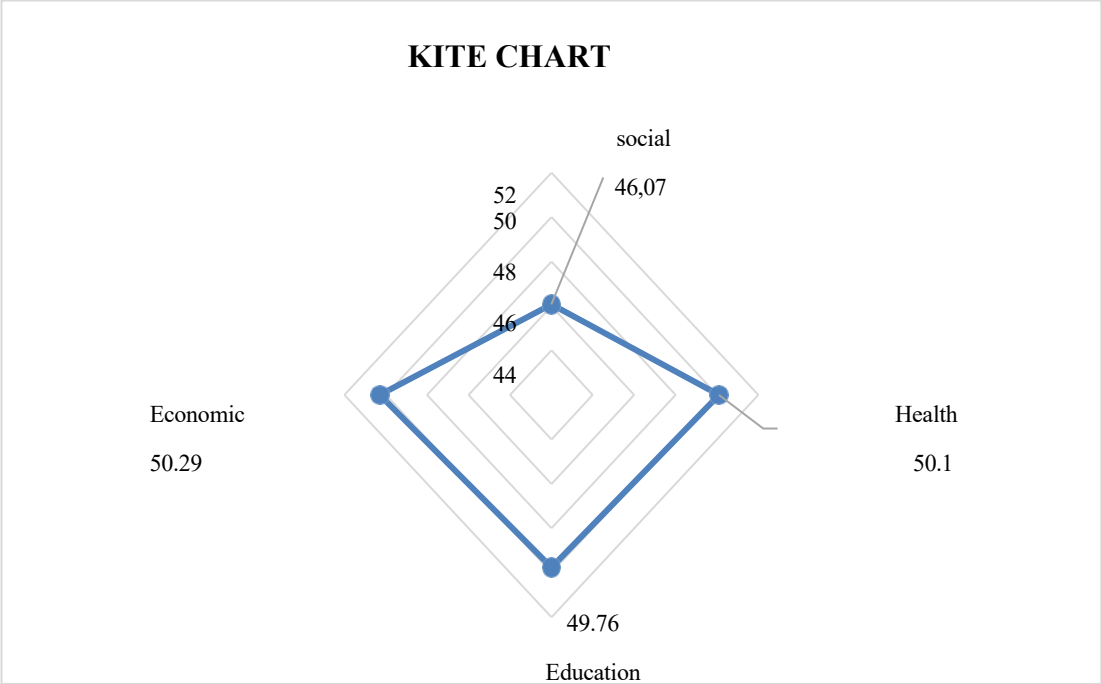

Figure 13. Comparative Analysis of Social Resilience Dimensions in Flood-Prone Areas of Kampar (Diamond-Shaped Radar Chart)"

The results of this visualization revealed an imbalance across dimensions. The social and educational dimensions were in the lowest positions, indicating an urgent need for interventions in social capital, disaster literacy, and community adaptive capacity. In contrast, the economic and health dimensions perform slightly better, but remain suboptimal. The index values, which are close to the midpoint (50), indicate that the community capacity remains fragile when facing flood risks. According to (Norris et al., 2008)**.** Community resilience is a process that links networks of adaptive capacities, including social, health, educational, and economic capital, with the ability to adapt successfully to adversity or disasters. Similarly, (Doorn and Copeland, 2020). Emphasizing building resilience effectively requires a holistic approach that simultaneously strengthens all forms of capital. Sustainability analysis, conducted using the MDS approach with the Rapfish method, indicates that the resilience capacity of the Kampar Regency community to flood disasters varies across different dimensions. The results for these four dimensions are listed in Table 2.

Table 2 Sustainability status of community resilience in adaptation and mitigation

Sustainability Dimension	MDS Value	Sustainability Status	S-stress	R^2
Multidimensional	49,06	Less Sustainable	0,14	0,94
Social	46,07	Less Sustainable	0,14	0,94
Education	49, 76	Less Sustainable	0,14	0,94
Health	50, 10	Moderately Sustainable	0,17	0, 93
Economy	50, 20	Moderately Sustainable	0, 16	0, 92

Source: Research Results, 2025.

Sustainability analysis, conducted using the MDS approach with the Rapfish method, indicates that the resilience capacity of the Kampar Regency community to flood disasters varies across different dimensions. The social dimension (46.07) and the education dimension (49.76) were categorized as less sustainable, while the health dimension (50.10) and the economic dimension (50.20) were at a moderately sustainable level. The overall multidimensional index score was 49.06. The analysis indicated that, in general, the community's resilience, adaptation, and mitigation capacities against disasters have not yet reached an optimal level of sustainability. Recent studies have highlighted that socio-ecological sustainability depends heavily on the synergy among social capital, health systems, education, and local factors (Chen et al., 2024). Substantial social capital has proven to be a crucial predictor of a community's response and recovery capacity following disasters (Abunyewah et al., 2023). Furthermore, the integration of disaster risk reduction (DRR) education into school curricula is considered a key factor in building disaster literacy and enhancing the adaptive capacity of communities (Masocha et al., 2025) In terms of health. Investments in primary health care systems have been globally recognized as an effective strategy to strengthen community resilience, with every USD 1 invested in disaster mitigation potentially yielding a return of up to 15 times the economic investment (UDRR, 2025). Meanwhile, the economic sector plays a significant role in post-disaster recovery through income diversification and strengthening of local livelihoods, as recommended by the Sendai Framework for Disaster Risk Reduction (2015–2030).

The findings revealed that the social dimension was the lowest among all aspects of resilience, indicating a critically weak capacity to respond effectively to flood disasters. This low performance is primarily driven by the lack of community involvement in disaster preparedness and policy-making processes, limited existence of organized local volunteer networks, and absence of structured communication platforms between residents and government institutions. Additionally, low levels of public awareness and disaster education contribute to reactive rather than proactive responses to flood events. Although local social capital, such as cooperation (*gotong royong*) and the role of traditional leaders, remains present, these assets have yet to be systematically incorporated into formal disaster risk reduction frameworks. This socio-structural gap highlights the urgent need for targeted community empowerment and integrative strategies to enhance social resilience–a vital pillar of community-based disaster management. The findings of this study, supported by stress values (<0.25) and R^2 (>0.90) from Rapfish analysis, indicate that the attributes used are sufficiently representative of the sustainability conditions in the Kampar Regency (UDRR, 2025). Accordingly, the following discussion explores each dimension of social, educational, health, and economic aspects in depth, along with the factors influencing sustainability levels and recommended intervention strategies to enhance community resilience.

4. Conclusion

This study introduces a novel methodological adaptation to the context of socio-ecological resilience in flood-prone rural communities in Indonesia by applying the Rapfish technique, which is commonly used in marine and fisheries sustainability assessments. By employing a multidimensional framework that integrates social, educational, health, and economic dimensions, this study provides a comprehensive analysis of community resilience, particularly in the Kampar Regency. The overall sustainability index of 49.06 categorizes the region as less sustainable, with the social (46.07) and education (49.76) dimensions being the most vulnerable. Meanwhile, the health (50.10) and economic (50.20) dimensions, although relatively stronger, remain only moderately sustainable and require targeted interventions. These findings directly address the identified research gap, namely the lack of integrated, quantitative, and context-specific assessments of social resilience in rural flood-prone areas. By revealing the sensitive attributes within each

dimension, such as community trust, participation, and access to disaster-related education, this study provides empirically grounded insights into strengthening local disaster preparedness and adaptation strategies. However, this study had several limitations. First, the sample size was limited to 105 respondents, which may not fully capture the diversity of resilience conditions across all subdistricts in the Kampar Regency. Second, the cross-sectional design limited the ability to observe temporal changes in resilience over time. Future research should consider expanding geographical coverage and employing longitudinal methods to track the dynamic shifts in resilience. Additionally, qualitative methods, such as in-depth interviews or focus group discussions, could complement the quantitative findings and offer deeper insights into cultural and institutional influences on resilience. Despite these limitations, this study makes a significant contribution to disaster risk reduction research by providing a replicable framework that aligns with the Sendai Framework for Disaster Risk Reduction. It equips policymakers and local governments with data-driven context-sensitive recommendations for designing integrated resilience-building programs. Ultimately, this research not only enriches academic discourse, but also underscores the need for localized, multidimensional strategies to foster sustainable community resilience, despite escalating flood risks.

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