Multidimensional Assessment of Village Resilience to Landslide Disasters Using the RAP-DRR Method

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Abstract. Landslides are one of the most frequent natural disasters in areas with steep slopes and high rainfall, such as Ngargoyoso Village, Karanganyar. This study aimed to assess the village's resilience level to landslide disasters from a multidimensional perspective using the RAP-DRR (Rapid Appraisal for Disaster Resilience in Rural areas) approach. The five resilience dimensions analyzed included social, economic, technological, institutional, and infrastructural aspects. Data were collected through questionnaire surveys and interviews with residents in landslide-prone areas, and were analyzed using the Multi-Dimensional Scaling (MDS) method in the Rapfish software. The results showed that the village's overall resilience index fell into the moderately sustainable category (score 55.64), with infrastructure being the strongest aspect (82.70) and technology the weakest (36.49). The social (63.35) and institutional (50.62) dimensions reflected relatively good community participation and institutional support, while the economic dimension (45.06) indicated a continued weakness in residents' financial resilience. These findings emphasized the importance of strategies to enhance community capacity, particularly in the technological and economic aspects, as a foundation for sustainable and adaptive disaster mitigation policies at the village level.

1 INTRODUCTION

Indonesia is one of the countries with a very high level of disaster vulnerability, particularly to hydrometeorological disasters such as floods, landslides, and strong winds [1]. Its location in the tropical region, right on the equator, and its topography dominated by mountains and hills make the country highly susceptible to extreme weather changes. Landslides are among the most frequent disasters, especially in areas with steep slopes and high rainfall. The risk of disaster increases when natural threats and vulnerabilities are not balanced by community mitigation capacity, as is the case in Central Java, where landslides have been the dominant disaster according to BNPB data since 2015. The natural characteristics of mountainous and hilly topography, combined with high rainfall,

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make areas such as Karanganyar Regency in Central Java particularly disaster-prone. Data shows that Ngargoyoso Subdistrict is the highest-risk area with 101 landslide cases, followed by Jatiyoso (34 cases) and Jenawi (34 cases), where natural factors like the steep slopes of Mount Lawu interact with anthropogenic factors such as land-use change and vegetation degradation.

The impacts are quite severe, including damage to agricultural land, settlements, and disruption of inter-village road access. The impacts are multidimensional and interconnected. Physically, landslides destroy vital infrastructure such as housing, roads, and clean water networks. Data from the Regional Disaster Management Agency (BPBD) shows that landslides have caused serious damage to agricultural land and infrastructure and have disrupted access between villages, even resulting in fatalities and significant economic losses. Economically, this disaster causes substantial material losses and disrupts community livelihoods [2]. Socially, it leads to psychological trauma and displacement, further increasing victims' vulnerability [3]. The accompanying ecosystem damage also reduces the environment's carrying capacity in the face of future disasters.

Facing this reality, strengthening community capacity in disaster preparedness becomes crucial. One strategy currently promoted by the government is the development of Disaster Resilient Villages (Desa Tangguh Bencana), which are villages with the independent ability to recognize threats, organize resources, and respond to and recover from disaster impacts quickly and effectively [4]. This program emphasizes not only physical preparedness but also the development of social, economic, institutional, and educational capacities. Village disaster resilience must be assessed thoroughly and systematically, given the complex and multidimensional impacts of landslides [5].

Therefore, an approach that can describe village conditions holistically and participatively is required. One relevant method is RAP-DRR (Rapid Appraisal for Disaster Risk Reduction) using the Rapfish tool, which can evaluate village resilience to landslides from multiple dimensions, including social, economic, environmental, infrastructure, and institutional aspects. This study aims to assess the resilience level of Ngargoyoso Village to landslide disasters from a multidimensional perspective using the RAP-DRR approach. The assessment not only seeks to identify the level of vulnerability and existing capacity of the village but also to determine the most influential dimensions of resilience and uncover the weakest aspects that should be prioritized in resilience-enhancement strategies. By thoroughly understanding real field conditions based on data, this study is expected to provide a foundation for the formulation of adaptive, targeted, and sustainable disaster mitigation policies, and to promote community empowerment as the main actor in disaster risk reduction.

2 MATERIALS AND METHODS

Location

The research was conducted in Ngargoyoso Village, Ngargoyoso Sub-district, Karanganyar Regency, an area known for its landslide risk due to its location on the slopes of Mount Lawu, unstable soil structure, and high rainfall intensity. The site was selected purposively based on landslide incident reports from local residents and risk potential determined by topography and land use.

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Materials

Data collection was conducted using a closed-ended questionnaire on an ordinal scale of 1 to 3. This simplified scale was selected to minimize respondent bias, ensure

clarity, and make it easier for residents with diverse educational backgrounds to provide consistent answers.

The respondents consisted of 35 residents from landslide-prone areas in Ngargoyoso Village. The sample size was purposively determined to ensure representation of households directly exposed to landslide risks, while also maintaining a balance between representativeness and feasibility. The choice of 35 respondents was considered appropriate given the constraints of time, budget, and accessibility in conducting field surveys in disaster-prone terrain.

Data Analysis

This study employed a quantitative descriptive approach using the RAP-DRR method (Rapid Appraisal for Disaster Risk Reduction). It covers five main dimensions including technology, institutions, infrastructure, economy, and social aspects. Data were analyzed using Multidimensional Scaling (MDS) through the Rapfish software (Rapid Appraisal for Fisheries), which was specially modified into RAP-DRR to evaluate village resilience to landslides in a participatory manner.

Table 1. Sustainability Status Category [6]

Index Value	Sustainability Status
< 25	Not sustainable
25 – 50	Less sustainable
50 -75	Moderately sustainable
> 75	Sustainable

The MDS process involved the following steps: (1) ordination analysis to calculate the sustainability index for each dimension (2) leverage analysis to identify key attributes, and (3) Monte Carlo analysis (95 percent significance level) to examine errors [7], with the goodness of fit evaluation based on stress values less than 0.025 and a coefficient of determination (R^2) close to 1.

The scoring results were visualized in a triangular kite diagram, where the symmetry of the angles represented the proportion of the sustainability index, and the highest angle indicated the most sensitive attribute. The final output was a radar chart mapping the sustainability level of each dimension on a scale of 0 to 100, categorized from unsustainable to highly sustainable, providing a holistic overview of the village's capacity for landslide risk mitigation. The category of sustainability status can be seen in Table 1.

3 RESULT AND DISCUSSION

3.1 Multidimensional Scale

Based on the data processing results, a total index score of 55.644 was obtained, which was categorized as moderately sustainable (See Table 2). Based on the mapping results in the diagram, it was evident that infrastructure was the strongest dimension with the highest score among all others, indicating that the village's physical preparedness for disaster readiness was relatively good. On the other hand, the technology dimension received the lowest score, reflecting the weak implementation of disaster-related technology such as early warning information systems and technical mitigation tools. The social and institutional dimensions were in the moderately sustainable category, indicating a relatively good level of awareness and community participation in

responding to landslide threats. In contrast, the economic dimension ranked low, suggesting the need to enhance household economic resilience against disaster risks.

Overall, Ngargoyoso Village demonstrated a fairly good level of resilience, particularly in terms of infrastructure. The high score in this dimension indicates that drainage systems, evacuation routes, and road accessibility are functioning relatively well, which provides a strong foundation for disaster preparedness. However, the low scores in the technological and economic dimensions reveal significant gaps. Limited knowledge and utilization of early warning systems, together with insufficient financial reserves, increase the community's vulnerability and may prolong recovery after landslides. These challenges suggest that efforts to improve technological literacy and to strengthen community-based economic institutions are essential. Enhancing these aspects would complement the existing infrastructure capacity and create a more comprehensive preparedness framework. In this way, resilience in Ngargoyoso can evolve beyond physical readiness toward a more integrated approach that combines infrastructure, technology, and economic empowerment.

Table 2. MDS Index Scores and Sustainability Level of Resilience

No.	Dimension	Number of Attributes	MDS Score	Sustainability Status
1	Social	5	63.35495684	Moderately Sustainable
2	Technology	5	36.48872868	Less Sustainable
3	Economy	5	45.05736489	Less Sustainable
4	Institutional	5	50.6222567	Moderately Sustainable
5	Infrastructure	5	82.70013449	Sustainable
	Total		55.6446883	Moderately Sustainable

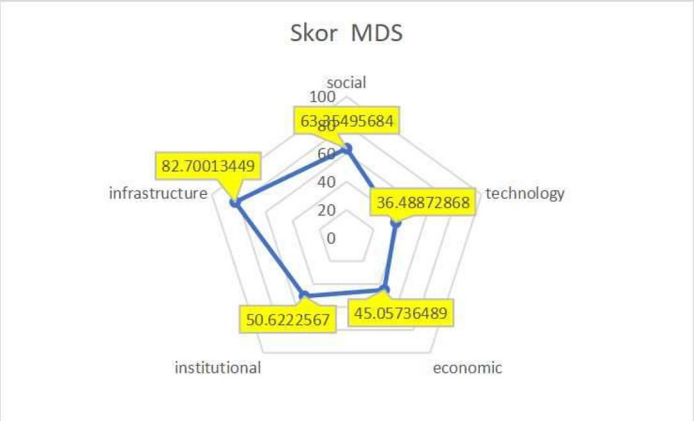

Fig. 1. Sustainability Index per Dimension in Ngargoyoso Village

3.2 Social Dimension

Based on the RAP-DRR analysis supported by the Monte Carlo test, it was revealed that the social dimension of the Ngargoyoso Village community demonstrated a sustainability index of 63.354, which fell into the moderately sustainable category. This result was not only supported by a reliability value of 0.705, which was significant at the

95 percent confidence level, but also reinforced by an optimal goodness of fit (stress value below 0.025 and R squared close to 1), confirming the validity of the research findings.

In the context of landslide disaster preparedness, which poses a real threat in this hilly region, three main pillars of social resilience emerged as key determinants. These included strong social solidarity with an RMS value of 8.727, adequate understanding of evacuation procedures with an RMS value of 8.311, and active participation in mitigation activities with an RMS value of 8.083. However, behind these strengths, significant challenges were identified in the low level of understanding of natural warning signs with an RMS value of 3.164. Only a few people in the study area were able to accurately recognize the early indicators of landslides.

This condition was further complicated by limited budgets for regular training, even though public enthusiasm for participation was relatively high. These findings aligned with the research of [8], which emphasized the crucial role of social capital in building disaster resilience in rural areas. To optimize existing social capacity, an integrated strategy is needed that combines the strengthening of local wisdom with technical interventions. The main recommendations include the development of educational modules based on local culture, the optimization of community-based early warning systems involving local leaders, and the increase of training frequency through strategic partnerships with universities and relevant institutions.

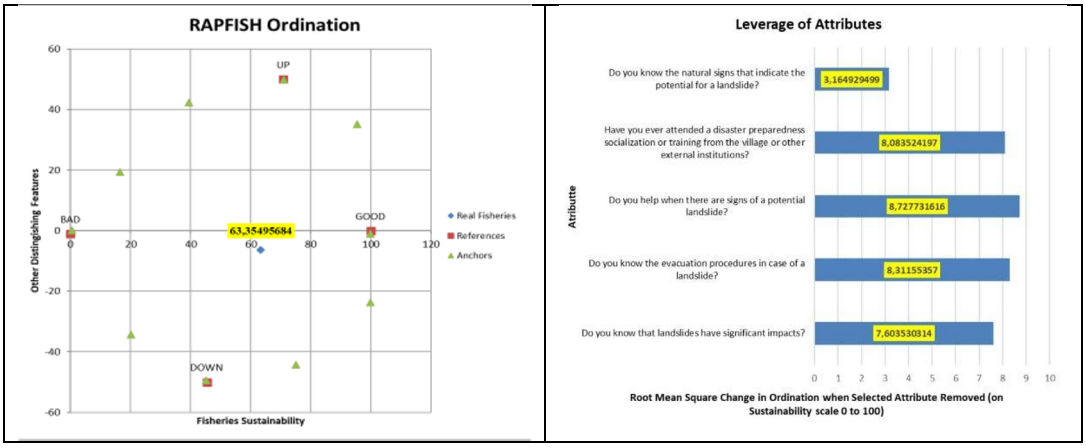

Fig. 3. Ordination and Leverage Graph of the Social Dimension

3.3 Economic Dimension

In the RAP-DRR analysis results, the economic dimension obtained a sustainability index score of 45.057, which was categorized as less sustainable. This score indicated that the economic resilience of Ngargoyoso Village residents in facing landslide disasters remained weak. Contributing factors included dependence on income sources located in landslide-prone areas, limited financial reserves, and minimal access to collective economic support. In general, the community did not yet have sufficient economic resilience to independently withstand and recover from the impacts of disasters.

The economic dimension covered aspects such as the exposure of livelihoods to disaster risks, the financial preparedness of the community in facing economic losses, and involvement in community-based economic support systems. The leverage analysis of attributes showed that among the five attributes examined, three had the most influence on the sustainability index. These were the impact of income loss due to landslides with an RMS value of 2.914, ownership of financial reserves such as savings or assets with an RMS value of 3.908, and participation in resilient economic groups such as cooperatives

or microfinance organizations with an RMS value of 3.951. These three attributes showed the highest RMS values, indicating that they played a major role in shaping the economic vulnerability of the village community to disasters.

This was in line with the study by [9], which found that cooperatives as community-based economic institutions played an important role in strengthening economic resilience, particularly by increasing access to capital, providing entrepreneurship training, and offering business management assistance. Cooperatives could serve as strategic instruments for promoting local economic self-reliance in post-disaster recovery. The other two attributes were the location of primary livelihoods in landslide-prone areas with an RMS value of 1.801 and direct experience of economic losses caused by disasters with an RMS value of 2.104. Although these had less influence, they remained relevant for understanding the structure of economic resilience in the village.

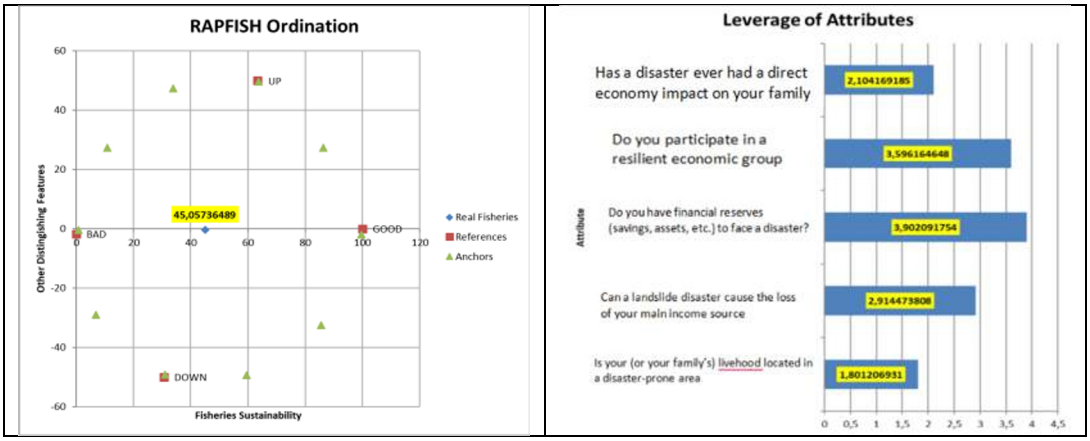

Fig. 4. Ordination and Leverage Graph of the Economic Dimension

3.4 Technological Dimension

Ngargoyoso Village faced serious challenges in the aspect of landslide mitigation technology. The RAP-DRR analysis results showed that the technology dimension in this village only achieved a sustainability score of 36.489, which fell into the less sustainable category. This low score was influenced by three main issues: limited mitigation training, low public understanding of early warning systems, and suboptimal soil conservation activities. The Monte Carlo statistical test (value 1.00487124) with an error rate below five percent confirmed that these findings were valid and required serious attention.

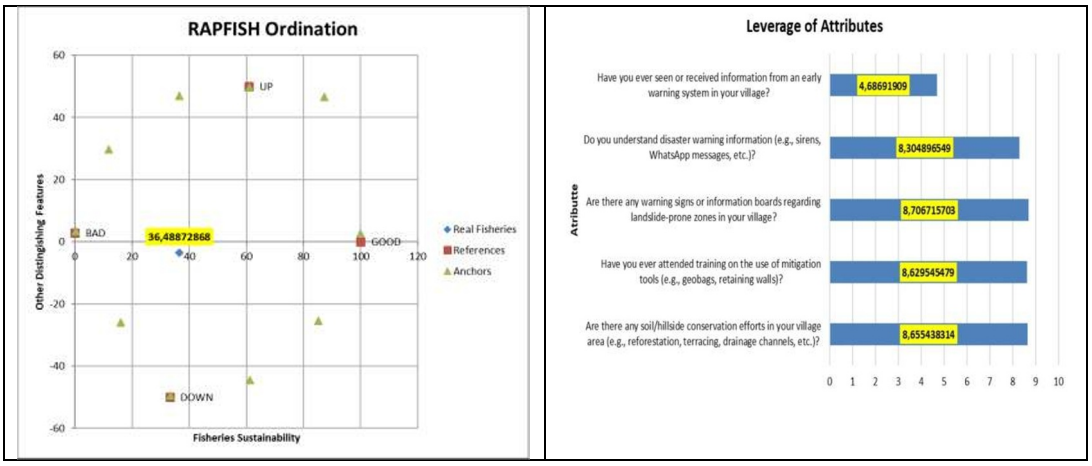

Fig. 5. Ordination and Leverage Graph of the Technological Dimension

The most critical factors hindering the progress of mitigation technology in Ngargoyoso were slope conservation with an RMS of 8.655, mitigation training with an RMS of 8.629, availability of warning signs with an RMS of 8.707, and understanding of disaster warning systems with an RMS of 8.305. The lack of training meant that residents were not familiar with using mitigation tools such as geobags. Meanwhile, the existing early warning systems, such as sirens or WhatsApp messages, were not effective because the community did not fully understand how to respond to them.

Reforestation and terracing activities as soil conservation efforts had also not been carried out optimally, even though research by [10] demonstrated that bioengineering approaches such as planting slope-stabilizing vegetation could significantly reduce landslide risk. Community participation in mitigation training remained very limited, involving only volunteer groups and a small portion of residents. In fact, community-based training, as recommended by [11], could be a solution to increase resident engagement. Experiences from other regions, such as Purbalingga which successfully implemented an IoT-based early warning system, could serve as inspiration for Ngargoyoso. However, given the limitations in technological literacy and infrastructure in this village, simpler approaches such as SMS-based applications or the use of traditional media like mosque loudspeakers and WhatsApp groups might be more effective.

3.5 Institutional Dimension

The institutional dimension in Ngargoyoso Village obtained a sustainability index of 50.622, which fell into the moderately sustainable category (Figure 6). This result was supported by the Monte Carlo test, which produced a value of 50.525 with a margin of only 0.09652, far below the five-point tolerance threshold. This small difference indicated that the analysis results were quite valid and could serve as a basis for assessing the institutional resilience of the village in facing landslide disasters.

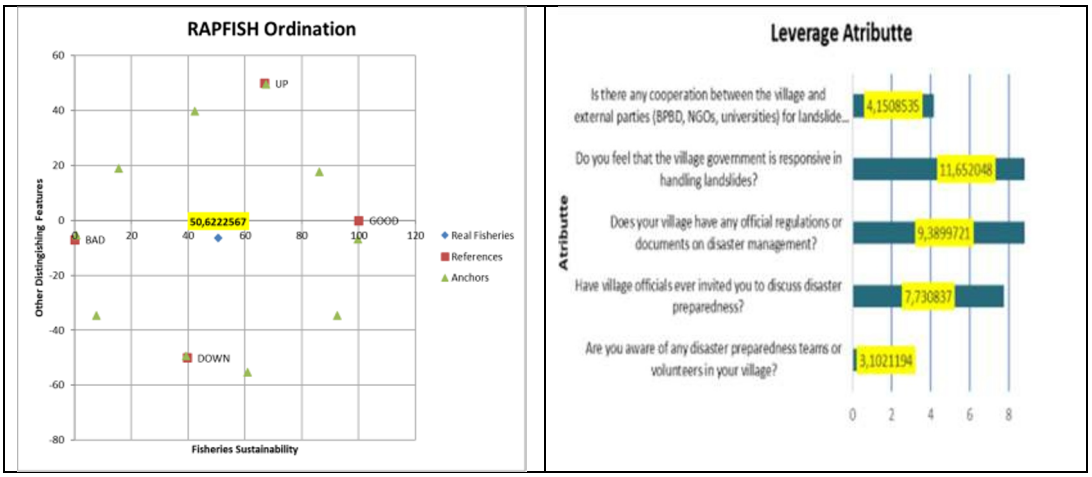

Fig. 6. Ordination and Leverage Graph of the Institutional Dimension

The institutional dimension in this study included the active roles of the village government, village officials, and community organizations in the formulation of disaster regulations, contingency planning, and regular mitigation training. These institutional roles were considered important because landslides posed a real threat in rural areas, including in Kendal Regency, Central Java, which had high landslide potential due to unstable morphology and land use practices [12].

This study focused on the involvement of village authorities and local institutions in mitigation processes, coordination, and decision-making related to disaster management. These findings were supported by research from [13], who stated that the ability of communities to deal with landslides was significantly influenced by institutional management at the village level, as well as the training and use of local wisdom among disaster volunteers. Furthermore, [14] emphasized that community resilience to disasters was strongly shaped by the strength of social capital and the role of local institutions, which encouraged more effective coordination and public participation.

The leverage analysis showed that out of the five assessed attributes, three had the greatest influence on the sustainability index. These included the responsiveness of the village government in handling landslides with an RMS of 11.652, the existence of official disaster-related documents or regulations with an RMS of 9.390, and the involvement of village officials in promoting disaster preparedness discussions with an RMS of 7.731. The other two attributes were cooperation with external parties such as the regional disaster management agency or NGOs, which had an RMS of 4.150, and the level of community knowledge regarding disaster response teams, which had an RMS of 3.102. Although these had less influence, they still contributed to the development of inclusive and adaptive institutions.

3.6 Infrastructure Dimension

The infrastructure dimension covered key aspects such as drainage conditions, road accessibility during rainfall, evacuation routes, housing location safety, and the availability of emergency evacuation facilities. The RAP-DRR analysis results showed that the infrastructure dimension achieved a sustainability score of 82.700, which fell into the sustainable category. The infrastructure dimension included crucial elements such as drainage conditions, road accessibility during heavy rain, evacuation routes, safety of residential locations, and the availability of emergency evacuation infrastructure.

Leverage analysis revealed that the three attributes with the highest influence on the sustainability index were the functionality of drainage during heavy rain (RMS = 10.237), the safety of main road access during the rainy season (RMS = 9.416), and the availability of clear and easily accessible evacuation routes (RMS = 8.765). These three attributes were the main determinants of the village's infrastructure resilience, as they directly affected evacuation speed, the smooth distribution of aid, and protection against infrastructure damage during disasters.

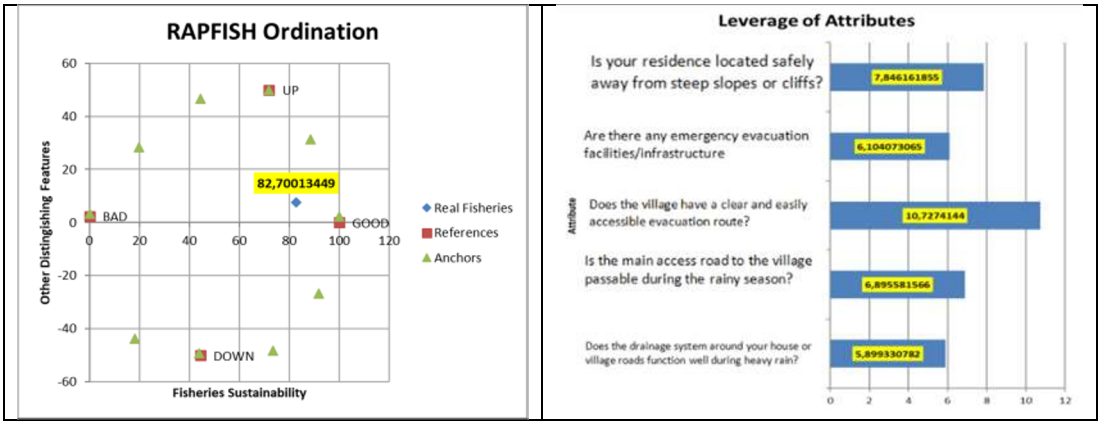

Fig. 7. Ordination and Leverage Graph of the Infrastructure Dimension

Two other attributes, namely the safety of residential locations from steep slopes or cliffs (RMS = 6.251) and the availability of evacuation infrastructure such as command posts, gathering points, or emergency tents (RMS = 5.604), although having lower influence, still contributed to community preparedness. The concept of resilient infrastructure was emphasized in the study by [15], which stated that infrastructure should be capable of absorbing disturbances, adapting, and recovering quickly from disasters through the principles of robustness, redundancy, rapidity, and resourcefulness.

Field findings showed that most areas of the village had drainage channels and evacuation route signs, although improvements were still needed in locations with steep terrain. However, infrastructure such as evacuation gathering points, directional signs, and evacuation routes were not yet fully connected or directed to clearly safe locations. Some gathering points were still located near hazard zones and lacked supporting emergency facilities. Although the infrastructure dimension had demonstrated good performance, efforts such as regular repair, relocation, and maintenance remained necessary to ensure the infrastructure functioned optimally in facing potential landslides.

4 CONCLUSION

This study shows that Ngargoyoso Village has a moderately sustainable level of resilience to landslide disasters, with a total index score of 55.64, based on a multidimensional assessment using the RAP-DRR method. Among the five dimensions analyzed, infrastructure scored the highest, indicating strong physical preparedness, while the technology and economic dimensions scored the lowest, reflecting limited early warning systems, disaster-related knowledge, and financial capacity. The social and institutional aspects are in a moderate condition but still require reinforcement through improved community participation, training, and cross-sector collaboration. To enhance overall resilience, targeted efforts are needed to strengthen the weaker dimensions

through disaster education, capacity building, and economic empowerment at the community level.

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