How to support recovery phase for landslide through livelihoods? case study: Kulon Progo Regency, Indonesia

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Abstract. The global climate is increasingly responsible for the frequency of extreme weather events, which have significant implications for vulnerable biological systems. Among these events, rainfall-induced landslides are recognized as one of the most severe geological disasters, particularly in Indonesia. The recovery phase is often the weakest link in disaster management implementation. This study aims to discern and assess the effects of the recovery phase on livelihoods in Kulon Progo, Indonesia, following landslides. The study examines the impact of human, social, physical, natural, and financial capital, as well as transformations in structure and process (TSP), on the recovery phase. The unit of analysis is households, with data collected from 300 households through stratified random sampling. Path analysis was applied to achieve the study's objectives. The findings reveal that human capital (0.376**), social capital (0.279***), physical capital (0.182*), and TSP (0.263***) have a direct effect on the recovery phase. Additionally, social capital (0.352***) and physical capital (0.180**) indirectly influence the recovery phase through TSP as a mediator. To strengthen the recovery phase in landslide disaster management, the study identifies seven activities that directly support the recovery phase and another seven that indirectly contribute to its reinforcement.

1 Introduction

In recent years, rapid urbanization and the expansion of human settlements have significantly altered land-use patterns across various regions [1, 2], leading to a marked reduction in ecological lands such as forests and wetlands [3, 4]. These areas, once crucial in maintaining environmental balance, have been increasingly replaced by urban development, resulting in the fragmentation of natural water networks and further compromising urban ecological systems [5, 6]. Compounding these challenges, the global phenomenon concerning rising temperatures has intensified severe droughts [7], particularly in tropical regions like Indonesia, where heavy rainfall poses a significant threat to fragile ecosystems. This has led to an increased frequency of rainfall-induced landslides, now recognized for being one of the greatest deadly catastrophes in the country [8].

In response to these growing threats, Indonesia has implemented a range of disaster risk reduction (DRR) policies aimed at mitigating the harmful effects within catastrophes [9-11]. These policies include government legislation, coordination among various agencies, community engagement, and comprehensive damage and loss assessments [12, 13]. However, despite these efforts, the rehabilitation and recovery processes following disasters, such as landslides, often remain slow and inadequate [14, 15]. This highlights the critical need for resilience in recovery, where community resources and strengths fulfil a crucial part in preserving growth along with wellness post-disaster [16-18]. Research suggests that the success of individual recovery efforts is closely linked to the overall success of the community [19-21], which depends on the availability and effective use of resources, including social networks and institutional support systems [22-24].

The risk of landslides in regions like Kulon Progo is particularly heightened by heavy rainfall, a consequence of worsening tropical climate conditions [25, 26]. Addressing this risk requires robust disaster preparedness strategies that consider the specific vulnerabilities of each location [27-29], including the need for full-time disaster management professionals and the integration of both formal and informal education and training initiatives [30-32]. This holistic approach is essential for enhancing community resilience and ensuring sustainable disaster management [33-35].

This study explores the relationship between Sustainable Livelihoods Assets (SLA) and the recovery phase following landslides in Kulon Progo Regency, Indonesia. The SLA framework, which integrates financial resources and organizational modifications [36, 37], is instrumental in identifying key areas for development initiatives aimed at improving the standard of living for impoverished and vulnerable communities,

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especially within the context of disaster preparedness and recovery [38, 39].

By focusing on the recovery phase after landslides, this research emphasizes the importance of rebuilding not just physical infrastructure but also the diverse assets that underpin community survival and prosperity, including human, natural, physical, financial, and social capital [40, 41]. The study aims to provide valuable insights into effective risk management practices that enhance local resilience and reduce exposure to future catastrophes, with a particular focus on the crucial role of individual motivation and societal resilience in preventing preparedness and recovery.

2 Data and methods

2.1 Study area

The research study focuses on Kulon Progo Regency, a region marked as green in Fig. 1. Located in Yogyakarta Province, Kulon Progo is particularly vulnerable to landslides, a risk exacerbated by its diverse topography and climatic conditions. This district encompasses 12 sub-districts and 88 villages, covering a total area of approximately 586 km². Within Kulon Progo, the largest sub-districts are Kokap, with an area of 73 km², and Samigaluh, spanning 69 km². Conversely, Wates is the smallest sub-district, occupying 32 km². The geographical coordinates of the study area range from 7° 38'42" S to 7° 59'3" S latitude and 110° 1'37" E to 110° 16'26" E longitude [42].

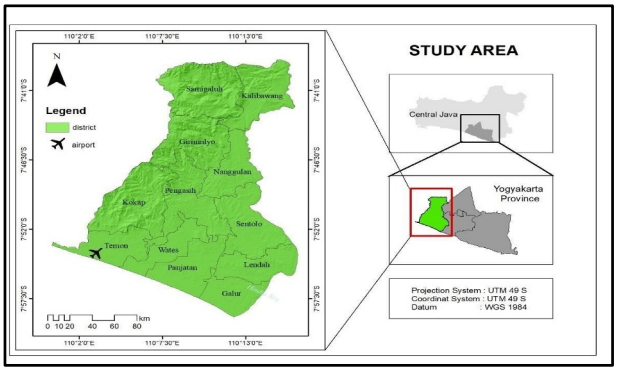

Fig. 1. Landslide hazard zonation map in Kulon Progo [43]

Kulon Progo features a varied topography, including lowland areas and elevated highlands with elevations ranging from sea level up to 1000 meters. The northern part of the district, notably mountainous, has elevations between 500 and 1000 meters. This region includes sub-districts such as Girimulyo, Kalibawang, Samigaluh, and Kokap. Despite their designation as conservation areas, these northern highlands are highly susceptible to severe landslides due to their steep slopes and frequent heavy rainfall [44].

2.2 Data collection

This research uses a quantitative approach, emphasizing the collection of primary data to provide a robust analysis of landslide recovery. The research framework is designed to establish benchmarks for effective landslide recovery through community-based approaches. Data collection was carried out in six villages within the Samigaluh district: Banjarsari, Gerbosari, Kebonhargo, Ngargosari, Purwoharjo, and Sinduharjo. This selection was informed by previous studies which have identified these villages as prone to rainfall-induced landslides, with the rainy season posing significant geotechnical hazards [45].

The focus of the analysis is on households, which are considered the primary unit of analysis. In this framework, disaster recovery is treated as the dependent variable. The independent variables are categorized into two main groups: household capitals and the transformation of structures and processes (TSP). Household capitals are classified into five distinct types: human capital (skills, education, and health), social capital (networks and relationships), natural capital (natural resources and environmental conditions), physical capital (infrastructure and equipment), and financial capital (monetary resources and economic stability).

The TSP aspect includes the integration and impact of cultural practices and beliefs on the recovery process. This component examines how traditional and culturally embedded practices influence recovery efforts and contribute to resilience. The study's sample comprises 300 households spread across the six selected villages. This sample size is intended to provide a representative overview of the impact of various capitals and TSP on disaster recovery outcomes. The data gathered will be analyzed to determine how different forms of household capital and transformations in structures and processes affect recovery from landslides, providing insights into effective community-based recovery strategies.

The study utilized both descriptive analysis and path analysis to meet its research objectives. Path analysis is particularly useful in this context because it allows for the estimation of the magnitude and significance of hypothesized cause-and-effect relationships among various variables, which are visually represented through path diagrams [46, 47]. The variables in the study were categorized as either ordinal or categorical. Categorical variables, which are qualitative, were grouped into distinct categories representing different qualities or characteristics. To further analyze the data, the study employed a Structural Equation Model (SEM) with a path analysis approach. This model distinguished between endogenous and exogenous variables [48-50]. The endogenous variables included livelihood assets and structural transformation. The exogenous variable was recovery, focusing on post-disaster management related to landslides, specifically examining structural transformation and the recovery phase. In this model, financial capital was represented solely by household income, which was measured on a monthly basis. Structural transformation was assessed through changes in cultural and religious aspects. The SEM equation used in the study was formulated to reflect these relationships and variables. The SEM equation was formulated as follows:

$$Recov_{11} = \beta_{11}\, transf_{11} + \beta_{12}\, HC_{12} + \beta_{22}\, SC_{22} + \beta_{32}\, NC_{32} + \beta_{42}\, PC_{42} + \beta_{52}\, FC_{52} \quad (1)$$

$$Transf_{11} = \beta_{12}\, HC_{12} + \beta_{22}\, SC_{22} + \beta_{32}\, NC_{32} + \beta_{42}\, PC_{42} + \beta_{52}\, FC_{52} \quad (2)$$

3 Results and discussion

To minimize the detrimental effects of catastrophes and ensure sustainable recovery, disaster management involves a comprehensive set of actions [51, 52]. The initial phase of recovery is a critical part of the process of catastrophe management, requiring a well-coordinated and community-focused approach to be effective [53-55]. This phase seeks not only to restore communities to their pre-disaster state but also to strengthen their resilience, making them better prepared for future disasters [56]. Essential components of a successful recovery strategy include building resilient infrastructure, enhancing institutional capacities, and implementing community-based recovery initiatives that target both current and future needs [57-60].

Post-disaster challenges are often complex, involving extensive infrastructure damage, socio-economic disruption, and psychological trauma [61-63]. Effective disaster management during the recovery phase requires a holistic approach that addresses these diverse issues [64]. Recovery efforts must go beyond the reconstruction of physical structures; they should also focus on the comprehensive restoration of lives, livelihoods, and local economies [65-67]. By utilizing local knowledge, fostering collaboration among stakeholders, and applying evidence-based strategies, disaster management can enhance recovery efforts as well as create a better tomorrow [68-71]. This approach is increasingly vital as global changes cause greater amounts of serious disasters, emphasizing the need for strong recovery frameworks as shown in Fig. 2 [72].

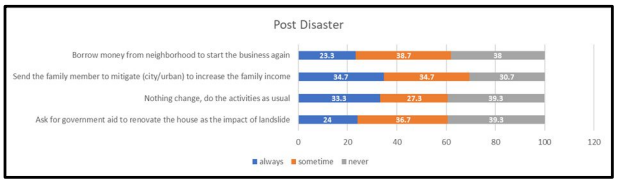

Fig. 2. Frequency analysis of the recovery phase (source: analysis, 2023)

In Samigaluh, the government's role in rehabilitating properties affected by landslides is evident. However, when government assistance is insufficient, households often adopt alternative recovery strategies. For instance, 38.7% of households seek financial support from neighbors, while 34.7% send family members to urban areas to supplement household income. This reliance on additional income sources highlights the limitations of government aid in fully addressing recovery needs. Additionally, 24% of households regularly request government assistance for home repairs following landslides, indicating a significant dependency on government policies and support during disaster recovery in Kulon Progo Regency.

The frequency analysis suggests that households in Kulon Progo Regency demonstrate a strong sense of independence and are less dependent on government assistance, with their disaster recovery largely supported by community cooperation. Path analysis further reveals that all household capitals—human, social, natural, physical, and financial—significantly impact the recovery phase, both directly and indirectly, at significance levels of 5% and 1%. The transformation of processes and structures is an endogenous variable, influenced by household capitals and the recovery phase, while the household capitals themselves serve as exogenous variables.

Figure 3 and 4 presents the quantitative coefficients for the direct and indirect effects on the recovery phase. The direct effects are quantified as follows: transformation of processes and structures (0.310**), human capital (0.041*), social capital (0.085*), natural capital (-0.070*), physical capital (0.076*), and financial capital (0.017*). Notably, natural capital has a negative direct effect on the recovery phase, suggesting that preserving or enhancing natural capital can reduce the need for extensive recovery efforts. This implies that effective natural resource management can help prevent landslides and mitigate disaster impacts.

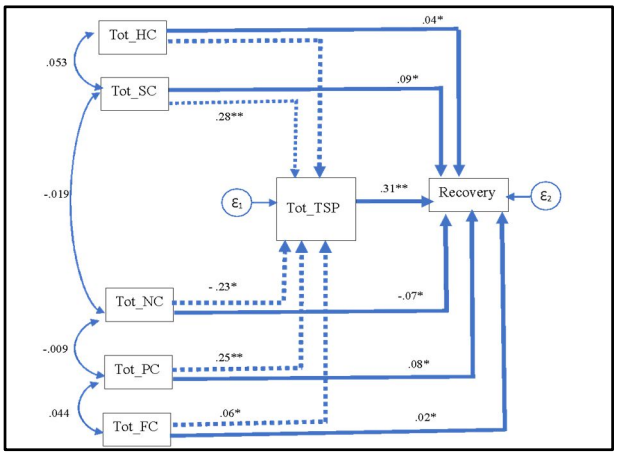

Fig. 3. Diagram of path analysis (source: analysis, 2023)

The transformation of processes and structures, which includes changes in policies, cultural practices, and belief systems, has the highest coefficient and greatest significance, underscoring its critical role in supporting recovery efforts. Households perceive these factors as essential for facilitating recovery after landslides. During the recovery phase, human capital is significantly impacted, requiring attention not only to the restoration of physical and economic assets but also to the psychological, health, and skill-based challenges faced by individuals in affected communities [73-75]. Providing psycho-social support, healthcare, and skill development is crucial for restoring the well-being, productivity, and resilience of community members, enabling them to contribute effectively to and benefit from the recovery process [76, 77]. Social capital also plays a vital role in recovery. Disasters can weaken community bonds, trust, and collaborative networks, making it essential to reinforce these ties through targeted [78, 79]. Strengthening social capital is critical, as robust

community networks facilitate mutual assistance, knowledge sharing, and collective action—key elements for achieving a comprehensive and sustainable recovery [80, 81].

The degradation of natural capital, such as ecosystems and biodiversity, can impede the recovery phase. Natural assets provide essential services like flood regulation, water purification, and erosion control, which are crucial for mitigating disaster impacts [82, 83]. Without these protective natural barriers, communities may face prolonged recovery periods and increased vulnerability to future disasters, emphasizing the crucial link between environmental health and disaster resilience [84-86]. Physical capital, including infrastructure, housing, and production facilities, often sustains the most direct damage during disasters and requires significant restoration efforts during recovery [87, 88]. The effectiveness and speed of recovery from physical damage determine the extent of enduring harm to this capital. Persistent deficiencies in physical assets can hinder socio-economic revitalization and heighten community vulnerability to future disasters [89, 90].

Total effects

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
transf_tot_index <-						
hc_total_index	.1335549	.0577515	2.31	0.021	.0203641	.2467457
sc_tot_index	.2755613	.0661721	4.16	0.000	.1458663	.4052562
nc_tot_index	-.2260253	.0778909	-2.90	0.004	-.3786886	-.0733621
pc_tot_index	.2464168	.0494285	4.99	0.000	.1495388	.3432949
log_pendapatan	.0563662	.019594	2.88	0.004	.0179627	.0947697
recov_index <-						
transf_tot_index	.3097725	.0670854	4.62	0.000	.1782875	.4412575
hc_total_index	.0413716	.020008	2.07	0.039	.0021567	.0805866
sc_tot_index	.0853613	.0276029	3.09	0.002	.0312607	.1394619
nc_tot_index	-.0700164	.0284973	-2.46	0.014	-.1258702	-.0141627
pc_tot_index	.0763332	.0225326	3.39	0.001	.0321701	.1204962
log_pendapatan	.0174607	.0071512	2.44	0.015	.0034446	.0314768

Fig. 4. Diagram of path analysis (source: analysis, 2023)

In the context of sustainable livelihoods, "transformation" refers to the essential changes needed to enhance the resilience, adaptability, and sustainability of livelihoods in the face of various vulnerabilities. Transformation of processes involves revising methods, strategies, and practices to achieve and maintain sustainable livelihoods. This type of transformation focuses on improving how resources are utilized and managed to enhance livelihood [91-94]. Conversely, transformation of structures pertains to systemic and institutional changes that shape societies and economies, which, in turn, influence livelihoods [95]. This includes changes in policies, governance, and institutional frameworks that affect how resources are distributed and accessed.

Recognizing the need for transformation in both processes and structures is vital for ensuring that livelihoods are not only sustained but can thrive under dynamic conditions. The goal is to create environments where individuals and communities have the necessary resources, capabilities, and flexibility to adapt, innovate, and maintain their well-being, even when confronted with shocks, stresses, or long-term challenges.

The indirect effects of various forms of capital—human, social, natural, physical, and financial—on the transformation of processes and structures are significant. Human capital, which includes skills, knowledge, health, and abilities, is notably impacted by these transformations. For instance, shifts in livelihood strategies or systemic changes may require the development of new skills and adaptive capacities for individuals and communities [96]. Moreover, transformations in institutional structures, governance mechanisms, or resource access can directly influence the quality of human capital by affecting health, education, and training opportunities.

Social capital, natural capital, physical capital, and financial capital also play substantial roles in influencing the recovery phase. Social capital, involving networks and relationships, has a considerable positive impact on recovery, as community connections facilitate support and resource sharing. Natural capital, which encompasses environmental resources, can negatively impact recovery if depleted, whereas physical capital, such as infrastructure, and financial capital, which includes economic resources, both significantly contribute to the recovery phase. Understanding these relationships underscores the importance of comprehensive and integrated approaches to both process and structural transformations in promoting sustainable livelihoods and enhancing recovery efforts.

4 Conclusion

The recovery phase in disaster management significantly influences livelihood assets, highlighting the interconnectedness of communities in the aftermath of a landslide. Effective recovery extends beyond merely rebuilding physical infrastructure; it also involves restoring and strengthening the critical assets—human, social, natural, physical, and financial—upon which households depend. A key lesson from disaster management is the role of livelihood assets during recovery. For instance, households frequently turn to local community networks for support in their recovery efforts. These community networks are vital for rebuilding businesses and improving overall well-being, as evidenced by 23.3% of households that rely on them. Such collective actions not only facilitate immediate recovery but also contribute to long-term resilience. Another common strategy involves sending a family member to work in urban areas to increase income and improve welfare after a disaster. This approach, adopted by 34.7% of respondents, underscores the importance of urban employment in providing crucial financial support to those who remain in disaster-affected regions. Diversifying income sources is essential for stabilizing livelihoods and rebuilding after a disaster. Providing targeted assistance to vulnerable households is also essential. Tailored support helps mitigate the impacts of future disasters and strengthens recovery capacity. Interventions that address the specific needs of at-risk households are key to ensuring effective recovery.

Policy recommendations for enhancing livelihood strategies include reinforcing assets through targeted interventions. Policies should focus on bolstering various forms of capital to ensure that households have the

necessary resources to recover and adapt. For example, Indonesia's "Panduan Mitigasi Desa Siaga Bencana Longsor" offers a framework for disaster mitigation at the village level, emphasizing community preparedness and response. Incorporating a willingness to pay (WTP) assessment into disaster guidelines is crucial for understanding community readiness to invest in preparedness and recovery efforts. Insights from WTP assessments enable the design of more effective and sustainable disaster management strategies. Additionally, Indonesia's national Community-based Disaster Management (CBDM) system underscores the importance of local communities in disaster preparedness and response. However, there is a need to develop practical, context-specific disaster guidelines to effectively address unique local challenges. Lastly, addressing the psychological impacts of disasters, such as post-traumatic stress, is critical. Enhancing cognitive appraisal processes, including insurance planning and financial protection measures, enables communities to better assess their situation, make informed decisions, and plan for future risks, thereby improving overall resilience to disasters.

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