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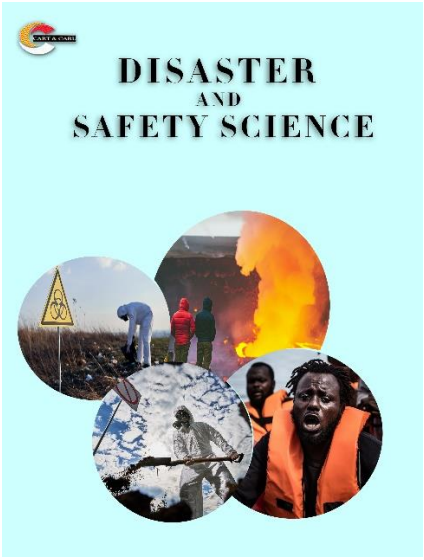

Comprehensive Environmental Management for Disaster Resilience: An Integrated Review of Pre-Disaster Preparedness, Post-Disaster Recovery, and Sustainable Restoration Strategies

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Abstract

Disaster resilience requires a holistic environmental management approach that integrates pre-disaster preparedness, post-disaster recovery, and sustainable restoration strategies. This paper provides a comprehensive review of these three pillars, emphasizing the importance of integrating environmental planning, climate adaptation measures, and sustainable development principles. Through an extensive review of scholarly literature, policy frameworks, and empirical studies, this study identifies best practices, challenges, and opportunities for enhancing disaster resilience. The findings suggest that a well-coordinated, multidisciplinary approach is essential for minimizing disaster impacts and ensuring long-term sustainability.

Keywords: Resilience, Disaster, Disaster Management, Environmental Management, Sustainability

Introduction

Resilience can be understood as an umbrella term encompassing a system's response to external stresses, major disruptions and new circumstances (Manyena 2006; Kapucu et al., 2013; Tiernan et al., 2019). While the concept has gained currency in many fields from ecology to psychology, in recent years it has become a prominent concept in the lexicons of climate change adaptation, disaster risk management, and sustainable development (Manyena 2006; Tiernan et al., 2019). Climate- and weather-related extreme events, such as floods droughts, heat waves, and bushfires, are increasing in frequency and intensity in many parts of the world (Intergovernmental Panel on Climate Change [IPCC], 2014; Raikes et al., 2019). Climate change, rapid urbanization and urban migration, and environmental degradation expose populations to greater risks to events and their impacts (IPCC, 2014; Djalante et al., 2013; Raikes et al., 2019).

How communities and countries prepare for anticipated events is important to the development of resilient systems (Toya & Skidmore, 2007; Rodriguez-Oreggia et al., 2013). Recovery from disaster can be hindered by inadequate community resilience capacity, impoverishment, and destitute facilities (Afolabi et al., 2023). Therefore, crucial attention is presently given to acquiring the mental ability of disaster-impacted communities to recuperate from the consequence of the event in the present or absent of foreign support (Afolabi et al., 2023).

The Sendai Framework for Disaster Risk Reduction emphasizes the importance of addressing disaster risk through four priorities: (i) understand disaster risk; (ii) strengthen disaster risk governance; (iii) invest in disaster risk reduction; and, (iv) enhance preparedness for response and to "Build Back Better" in recovery and rehabilitation (United Nations Office of Disaster Risk Reduction [UNISDR], 2015).

Disaster management seen from the perspective of community perception is very urgent and important to know as basic knowledge for the community about what to do in the face of disasters (Asih et al., 2023). The main components of disaster risk reduction (DRR) usually include disaster risk assessments, early warning systems, community awareness and education, and sustainable development. Risk assessment involves identifying, assessing, and analyzing the risks associated with various hazards, including their potential impact on society and the environment (Asih et al., 2023). Meanwhile, early warning systems may help minimize the impact of disasters by alerting populations of imminent catastrophes in a timely and precise manner. (Chisty, 2020; Asih et al., 2023).

Disasters, whether natural or anthropogenic, pose significant challenges to communities, ecosystems, and economies worldwide. Environmental management plays a crucial role in enhancing resilience by mitigating risks, preparing for crises, and fostering sustainable recovery. This paper aims to provide an integrated review of comprehensive environmental management strategies that contribute to disaster resilience. The objectives are to analyze key concepts, frameworks, and case studies that demonstrate effective disaster management.

Disaster Resilience and Environmental Management: An Overview

Disaster Resilience

Disaster resilience refers to the ability of a system, community, or society to resist, absorb, adapt, and recover from disaster impacts efficiently (Cutter et al., 2008). It encompasses preparedness, response, recovery, and adaptation strategies to minimize vulnerability and enhance coping mechanisms. Disaster resilience is multidimensional, incorporating social, economic, infrastructural, institutional, and environmental components (Ainuddin & Routray, 2012). These dimensions collectively determine a society's ability to withstand and recover from hazards.

i Social Resilience: Includes education, awareness, and social capital that influence community participation in disaster risk reduction (Paton & Johnston, 2017).
ii Economic Resilience: Encompasses financial mechanisms such as insurance, diversified income sources, and economic adaptability (Rose, 2017).
iii. Infrastructure Resilience: Relates to the robustness and redundancy of critical infrastructure systems (Bruneau et al., 2003).
iv. Institutional Resilience: Concerns governance, policies, and frameworks that shape disaster management practices (Tierney, 2019).
v. Environmental Resilience: Focuses on ecosystem-based solutions to mitigate disaster risks (Munang et al., 2013).

Building disaster resilience refers to the ability to recover from a disaster and return to a state of normalcy or a new normal, including restoring services and livelihoods (Bailey et al., 2024). At least conceptually we could expect that within the context of this study, disaster resilience could be achieved by developing and implementing disaster management plans, investing in robust infrastructure that can withstand disaster impacts, fostering community engagement and participation in disaster preparedness, promoting funding mechanisms for disaster response and recovery, and encouraging partnerships among the government, private sector, and civil society for resource sharing and collaboration (Seyedin et al., 2011; Chandrasekhar, 2012; Abe & Ye, 2013; Gil-Rivas & Kilmer, 2016; Meyer & Schwarze, 2019).

Environmental Management in Disaster Risk Reduction

Environmental management is crucial in disaster risk reduction (DRR) by promoting sustainable land use, resource conservation, and ecological restoration. Environmental management involves the sustainable use and conservation of natural resources to support ecological balance and resilience (UNEP, 2015). It serves as a preventive mechanism against disasters by maintaining ecosystem integrity, which in turn provides natural protection against hazards such as floods, landslides, and droughts (Munang et al., 2013). Ecosystem-Based Disaster Risk Reduction (Eco-DRR) emphasizes the use of natural systems to mitigate disaster risks (Estrella & Saalismaa, 2013). Key approaches include:

i Wetland Restoration: Wetlands act as natural buffers against floods and storm surges (Barbier et al., 2011).
ii Mangrove Conservation: Mangroves protect coastal areas from erosion and storm impacts (Alongi, 2014).
iii Reforestation and Afforestation: Forests prevent landslides and enhance carbon sequestration (Chazdon, 2008).

Strategies and Approach to Disaster Management and Resilience Building

Today, global human activity is systematically undermining the biosphere's ability to provide us with ecosystem services to the extent that we are limiting our ability to live well into the future (Livitt et al., 2011). Human-caused ecological degradation has resulted in a number of issues that affect the socio-ecological system, such as increased natural hazard risks and disaster occurrences. Future trends predict that natural disaster events will continue to increase if society continues to function along its current, unsustainable path. However, proper disaster management (DM) provides opportunities to reduce human vulnerability to natural hazards both before and after a disaster event, and to move society towards socio-ecological sustainability (Livitt et al., 2011).

Disaster management requires consideration of governance and management. Governance refers to the system of institutions, mechanisms, policy and legal frameworks, and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy (United Nations [UN] 2016; Bressers et al., 2016). Management refers to the organization, planning and application of measures preparing for, responding to and recovering from disasters (UN, 2016). Responses can be structural (e.g. dams, flood levies, evacuation shelters) or non-structural (e.g. building codes, land-use planning laws and regulations, public awareness programmes), and could be reactive (i.e. response oriented) or pro-active (i.e. risk reduction). Understanding the variety of responses is important because of the implications that those responses and systems have on pathways for development (Collins, 2018; Thomalla et al., 2018).

Pre-Disaster Preparedness

Of relevance to pre-disaster planning and preparedness is the interaction with human development in governance and management (Toya & Skidmore, 2007; Rodriguez-Oreggia et al., 2013). As the UNISDR (2015) notes, investment into capacities to strengthen disaster management has increased; however, the application of policies, norms, standards and regulations on disaster risk reduction and the integration with human development continues to challenge existing governance models in many countries (Raikes et al., 2019). Effective preparedness strategies reduce vulnerabilities, enhance community resilience, and ensure a swift response when disasters occur (UNDRR, 2020). Various dimensions of pre-disaster preparedness, including risk assessment, early warning systems, community engagement, policy frameworks, and capacity building.

i Risk Assessment and Hazard Mapping: Risk assessment is the foundation of pre-disaster preparedness, providing critical information on potential hazards, vulnerabilities, and exposure levels (Alexander, 2018). Hazard mapping enables decision-makers to prioritize areas that require urgent intervention. According to Cutter et al. (2016), risk assessments must integrate socio-economic, environmental, and infrastructural factors to ensure a holistic approach to disaster preparedness.

ii Early Warning Systems: Early warning systems (EWS) are essential in reducing disaster-related losses by providing timely alerts to communities at risk. Effective EWS integrate technological advancements, meteorological data, and communication strategies to enhance preparedness (Basher, 2019). However, challenges such as inadequate infrastructure and limited access to real-time information hinder their effectiveness in many developing regions (WMO, 2021).

iii. Community Engagement and Public Awareness: Community participation is a cornerstone of successful disaster preparedness. Raising awareness through education, training, and simulations helps communities develop coping mechanisms and improve response strategies (Paton & Johnston, 2017). Studies by Shaw and Takahashi (2020) indicate that community-led preparedness programs yield better outcomes than top-down approaches, as they empower local populations with the necessary knowledge and skills.

iv. Policy Frameworks and Institutional Arrangements: Robust policy frameworks ensure the sustainability of disaster preparedness efforts. Governments and international agencies must collaborate to formulate policies that integrate disaster risk reduction (DRR) into national development plans (UNISDR, 2015). The Sendai Framework for Disaster Risk Reduction 2015-2030 highlights the importance of institutional coordination and resource allocation in enhancing disaster preparedness (UNDRR, 2015).

v. Capacity Building and Resource Mobilization: Capacity building involves equipping emergency responders, local authorities, and non-governmental organizations (NGOs) with the necessary tools and skills to handle disasters effectively (Tierney, 2019). Resource mobilization, including financial investment in infrastructure and technological innovations, is critical to strengthening preparedness efforts (Kelman et al., 2020). Without adequate resources, disaster preparedness remains insufficient, leading to increased disaster-related casualties and economic losses.

Post-Disaster Recovery

Pre-disaster recovery planning is a proactive approach that enhances resilience by preparing for post-disaster recovery before a disaster strikes. This strategy ensures a swift and effective response, reducing long-term socio-economic and environmental impacts (Smith & Wenger, 2019). The key components of pre-disaster recovery, including strategic planning, governance frameworks, community engagement, resource allocation, and capacity building.

i Strategic Planning for Recovery: Pre-disaster recovery planning involves setting long-term recovery goals, identifying potential challenges, and developing actionable strategies (Olshansky et al., 2018). A well-structured recovery plan integrates risk assessment, infrastructure resilience, and economic revitalization to ensure sustainable rebuilding efforts. According to Schwab (2020), pre-disaster recovery planning must align with broader disaster risk reduction (DRR) strategies to enhance

overall community resilience.

ii. Governance and Institutional Frameworks: Effective governance is crucial in coordinating pre-disaster recovery efforts. Governments and disaster management agencies must establish clear policies and regulations that define roles, responsibilities, and resource distribution (Tierney, 2019). The Sendai Framework for Disaster Risk Reduction 2015-2030 underscores the importance of institutional preparedness and inter-agency collaboration in recovery planning (UNDRR, 2015).

iii. Community Engagement and Social Capital: Incorporating community perspectives into recovery planning strengthens local resilience and ensures culturally appropriate recovery measures (Aldrich & Meyer, 2015). Studies indicate that communities with strong social capital recover faster due to mutual support networks and collective action (Nakagawa & Shaw, 2020). Public participation in decision-making processes enhances trust and facilitates more inclusive and effective recovery strategies.

iv. Resource Allocation and Financial Preparedness: Pre-disaster recovery planning requires adequate financial resources to support reconstruction and rehabilitation efforts. Establishing disaster funds, insurance mechanisms, and contingency budgets is essential to prevent delays in post-disaster recovery (Hallegatte et al., 2017). Financial preparedness also includes investments in resilient infrastructure and sustainable urban development (World Bank, 2021).

v.Capacity Building and Knowledge Management: Capacity building focuses on training emergency responders, local authorities, and community organizations in disaster recovery principles (Paton & Johnston, 2017). Knowledge management, including lessons from past disasters, helps refine recovery plans and improve response effectiveness (Boin & Lodge, 2016). Integrating scientific research, technological innovations, and indigenous knowledge enhances adaptive recovery approaches (Kelman et al., 2020).

Sustainable Restoration

Sustainable restoration in disaster management is an essential approach that ensures long-term resilience by integrating environmental, social, and economic considerations into post-disaster recovery efforts. Unlike traditional recovery strategies that prioritize short-term solutions, sustainable restoration aims to rebuild communities while minimizing future vulnerabilities (Kelman et al., 2020). The key components of sustainable restoration, including ecological restoration, resilient infrastructure, community participation, and policy integration.

i Ecological Restoration and Environmental Sustainability: Ecological restoration plays a crucial role in sustainable disaster recovery by promoting biodiversity conservation and reducing environmental degradation. Post-disaster restoration should focus on restoring natural ecosystems such as wetlands, forests, and mangroves, which serve as natural buffers against future hazards (Turner et al., 2016). According to Gunderson and Holling (2017), resilient ecosystems can enhance disaster risk reduction (DRR) by mitigating the impacts of floods, storms, and landslides.

ii Resilient Infrastructure and Green Building Practices: Developing resilient infrastructure is vital to ensuring sustainable restoration. Incorporating green building techniques, such as the use of renewable energy sources, climate-adaptive designs, and sustainable materials, can enhance structural integrity and reduce carbon footprints (Bosher et al., 2019). The concept of "build back better," as emphasized in the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015), underscores the importance of constructing disaster-resilient buildings that can withstand future hazards.

iii Community Participation and Social Equity: Sustainable restoration must be inclusive, ensuring that marginalized and vulnerable populations have a voice in recovery efforts. Community-led approaches, such as participatory planning and local knowledge integration, foster a sense of ownership and long-term commitment to resilience (Gaillard & Mercer, 2019). Studies suggest that post-disaster recovery is more effective when communities are actively engaged in decision-making and capacity-building initiatives (Paton & Johnston, 2017).

iv Policy Integration and Institutional Coordination: Effective policy frameworks are necessary to support sustainable restoration efforts. Governments and international organizations must align disaster recovery plans with broader sustainability goals, such as the United Nations Sustainable Development Goals (SDGs) (UNDP, 2020). Policy coordination among stakeholders, including government agencies, non-governmental organizations (NGOs), and private sectors, can ensure efficient resource allocation and long-term recovery planning (Olshansky et al., 2018).

Community Level Resilience Building

Community resilience involves the capability of community members to intentionally take calculated, goal-oriented, and cooperative actions to assuage from destructive impacts of unwanted events such as disasters. Similarly, to personal resilience, community resilience entails the desire, attitude, beliefs, mindset, hope, and resources (Pfefferbaum et al., 2013).

Building resilience in rural community faces obstacles from policy frameworks that do not cater adequately to rural needs in integrating data for efficient planning (Godschalk, 2014). Issues like access to training also pose challenges (Freeman & Ashley, 2017). Community engagement is a theme in the literature that emphasizes the importance of communication and transparency for successful recovery endeavors (Garcia, 2021). Those who are most familiar with the issues are best suited to devise solutions, highlighting the value of community knowledge and engagement (Cutter & Finch, 2008). Ensuring long-term resilience involves developing tailored solutions that consider the social, economic, and environmental characteristics of rural areas (Garcia, 2021). By empowering communities through participation and innovative initiatives, resilience can be greatly improved (Afolabi et al., 2023). Research and policymaking play a role in shaping strategies to tackle the obstacles faced by these communities (Garcia, 2021).

In recent decades, scholars have linked community resilience to certain attributes/features using various methodologies and instruments. Madsen and O'Mullan (2016) linked community resilience to attributes such as social connectedness, optimistic acceptance, learning tolerance and patience, and learning from the past for the future. Shim and Kim (2015) established three-dimensional resilience factors; biophysical, built-environment, and socioeconomic conditions. Alshehri et al. (2013) indicated that factors such as age, education level, economic, risk perception, access to sources and willingness, responsibility, and faith are essential to building community resilience to disaster. There is literature on quantifying community resilience (Cutter et al., 2008; Pfefferbaum et al., 2016; Cai et al., 2016; Afolabi et al., 2023). Disaster recovery and resilience have historically been focused on urban areas. The literature extensively covers the challenges faced by cities in terms of social vulnerability issues and infrastructure damage post-disaster. However, there is a lack of exploration into the struggles of rural communities, which often deal with issues like isolation and limited access to services (Garcia, 2021).

Future Directions and Conclusion

Disasters, both natural and human-induced, pose significant challenges to human societies and ecosystems. Effective disaster resilience and environmental management strategies are essential in mitigating risks and ensuring sustainable recovery. Pre-disaster preparedness is a multifaceted approach that requires collaboration among stakeholders, investment in risk assessment and early warning systems, and active community participation. Policymakers must prioritize DRR measures to build resilient communities and minimize disaster impacts. Pre-disaster recovery planning is a fundamental component of disaster resilience, ensuring efficient recovery efforts and minimizing long-term disruptions. Strategic planning, governance, community involvement, financial preparedness, and capacity building are essential elements in effective recovery frameworks. Despite the benefits of sustainable restoration, several challenges hinder its implementation. Financial constraints, political instability, and lack of technical expertise often limit the adoption of sustainable practices in disaster recovery (Hallegatte et al., 2017). Future research should explore innovative financing mechanisms, such as green bonds and public-private partnerships, to support sustainable restoration efforts (World Bank, 2021).

Disaster resilience and environmental management are interconnected fields that require integrated approaches for effective disaster risk reduction. Sustainable environmental practices, technological innovations, community-based initiatives, and strong governance frameworks collectively enhance disaster resilience. Sustainable restoration in disaster management is a multidimensional approach that integrates ecological, infrastructural, social, and policy-driven strategies to enhance long-term resilience. By prioritizing environmental sustainability, community engagement, and resilient infrastructure, disaster recovery efforts can contribute to a more sustainable and disaster-resilient future. Comprehensive environmental management is essential for enhancing disaster resilience. By integrating pre-disaster preparedness, post-disaster recovery, and sustainable restoration strategies, communities can effectively mitigate risks and ensure long-term sustainability. The findings underscore the need for interdisciplinary collaboration, policy innovation, and community engagement in building resilient societies.

Declaration of Competing Interest

The author declares no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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