Food Logistics Preparedness and Community Health Resilience in Flood-Prone Areas: The Role of Individual, Structural, and Environmental Factors

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ABSTRACT

Food security and food logistics preparedness are essential components in strengthening community health resilience in flood-prone areas. Recurrent flooding disrupts food distribution systems and increases the risk of malnutrition and environment-related diseases, highlighting the need for evidence-based disaster preparedness strategies. This study aimed to analyze the influence of individual factors (age, sex, and education level), structural factors (food distribution effectiveness, food logistics preparedness, and policy support), and environmental factors (infrastructure and health facilities) on community health resilience in flood-affected areas. A quantitative study with a cross-sectional design was conducted. Data were collected through structured questionnaires administered to community members and stakeholders, as well as document reviews of disaster management and food distribution reports. Community health resilience was directly influenced by age, sex, education level, and the effectiveness of food distribution. In addition, indirect effects were observed from food logistics preparedness, environmental factors, policy support, and the availability of health facilities. In conclusion, community health resilience in flood-prone areas is shaped by the interaction of individual, structural, and environmental factors. Strengthening food logistics systems and policy support is therefore essential to enhance community health resilience during flood disasters.
Keywords: flood-prone areas; community health resilience; food logistics preparedness; food distribution effectiveness; policy support

INTRODUCTION

Food security and health logistics preparedness are two fundamental pillars for sustaining community well-being, particularly in disaster-prone regions such as flood-affected areas [1,2]. Flood events frequently disrupt transportation networks, damage infrastructure, and interrupt supply chains, which in turn limits the distribution of food and access to essential health services. These disruptions may trigger nutritional crises, increase the incidence of communicable diseases, and worsen existing social inequalities among vulnerable populations [3–5]. In many developing regions, limited preparedness in food and health logistics systems further exacerbates the negative impacts of disasters, especially when emergency response mechanisms are not adequately coordinated or supported by resilient infrastructure [4,6].

Recent global studies have highlighted the growing vulnerability of food systems to climate-related shocks and disasters. Climate variability, extreme weather events, and environmental degradation have intensified risks to food availability, accessibility, and stability, thereby threatening the sustainability of food systems worldwide [6,7]. A number of studies emphasize that inefficient or non-responsive logistics distribution systems can significantly worsen disaster outcomes, particularly in terms of food insecurity and deteriorating public health conditions [8,9]. International organizations such as the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have identified food scarcity and disrupted health services during crises as major obstacles to achieving Sustainable Development Goal (SDG) 2 (Zero Hunger) and SDG 3 (Good Health and Well-being) [10,11].

The Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report (AR6) also emphasizes that food and health systems will become increasingly vulnerable due to multidimensional climate change impacts, including floods, droughts, and other extreme events [12]. Systemic failures in food and health systems during disasters is one of the most pressing global risks facing societies today [13]. The developing countries require resilient logistics systems to cope with recurrent disaster cycles and minimize humanitarian risks [14].

In Indonesia, seasonal flooding continues to threaten rural communities where transportation and distribution infrastructures are limited. For example, villages such as Jerukgulung in Balerejo Subdistrict, Madiun Regency frequently experience seasonal floods that disrupt logistical routes and reduce access to food supplies and healthcare services [15]. These conditions demonstrate the importance of strengthening community-based logistics preparedness and improving coordination between local authorities, health services, and disaster management institutions.

At the national level, Indonesia's Long-Term National Development Plan (RPJPN) 2025–2045 and the National Research Priority (PRN) 2020–2024 emphasize the importance of strengthening climate-resilient logistics systems to support sustainable development and achieve SDG targets [16]. Previous studies have identified food logistics preparedness during emergencies as a key indicator of community resilience, particularly in disaster-prone areas [17]. Efficient food logistics systems can accelerate post-disaster recovery, reduce mortality, and ensure timely access to essential supplies for affected populations [18,19].

Furthermore, international development institutions such as the United Nations Development Programme (UNDP), FAO, and the Asian Development Bank (ADB) highlight that strengthening community-based food and health logistics systems should become a priority in regional development planning. Integrating local ecosystems and community networks into logistics systems can enhance adaptability to climate change and improve disaster resilience [20]. Evidence also suggests that logistics models built upon local data, community participation, and decentralized distribution networks are more resilient in disaster situations. Therefore, developing evidence-based models for food logistics management in flood-prone areas is essential to support disaster preparedness and protect community health during major natural disasters [21].

This study aimed to analyze the influence of food logistics preparedness, food distribution effectiveness, individual factors (age, sex, and education level), environmental factors, and policy support on community health resilience in flood-prone areas.

METHODS

This study was conducted from June to August 2025 in flood-prone areas of Madiun Regency, East Java, Indonesia. An analytic observational study with a cross-sectional design was employed. The study population consisted of residents affected by flooding in the selected areas, totaling 2,221 individuals according to local disaster management records. A sample of 134 participants was selected using stratified random sampling to ensure adequate representation of demographic characteristics. Participants were recruited from community members residing in flood-affected villages during the study period.

The dependent variable in this study was community health resilience. Independent variables included age, sex, education level, and the effectiveness of food distribution. In the analytical framework, food logistics preparedness, policy support, environmental factors, and the availability of health facilities were treated as mediating variables that potentially mediated the relationship between individual factors and community health resilience. Data were collected using structured questionnaires to obtain information on individual characteristics, perceptions of food distribution effectiveness, food logistics preparedness, and levels of community health resilience. Additional information regarding policy support, environmental conditions, health facilities, and food distribution during disaster situations was obtained through guided interviews and document reviews of disaster management and food distribution reports.

Data analysis was conducted in several stages. Univariate analysis was used to describe respondent characteristics and the distribution of each variable. Bivariate analysis was applied to identify relationships between variables. Multivariate analysis was subsequently performed using path analysis to examine both direct and indirect effects among independent variables, mediating variables, and the dependent variable. The path analysis procedure included model specification to define causal relationships among variables, model identification to ensure the feasibility of parameter estimation, parameter estimation to obtain path coefficients, evaluation of model fit, and model respecification when necessary. Path coefficients were interpreted based on the direction and magnitude of the relationships, where larger coefficients indicated stronger effects on community health resilience.

RESULTS

The characteristics of the research subjects are presented in Table 1. Based on the findings, most participants were aged >45 years, accounting for 81 subjects (60.4%). Regarding educational characteristics, the majority of respondents had a low level of education, totaling 93 subjects (approximately 40% of the study population). In terms of food distribution effectiveness, most respondents reported effective food distribution, with 108 subjects (80.6%) indicating that food distribution systems functioned adequately.

Furthermore, policy support was reported as supportive by the majority of respondents (83.6%). Environmental factors also showed favorable conditions (70.9%) indicating supportive environmental conditions in their communities. Concerning health facilities, most participants reported the availability of supporting health services (78.4%). Community health resilience was predominantly categorized as good (77.7%). Lastly, regarding food logistics preparedness, most respondents indicated that logistics preparedness was adequate (79.1%) reporting readiness.
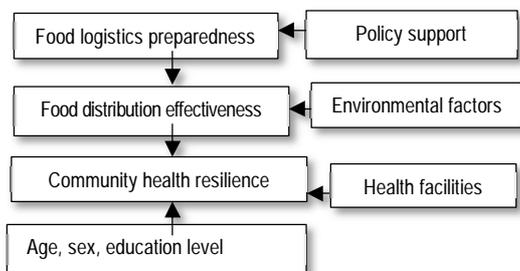

Figure 1. Specification of the path analysis model of community health resilience

Table 1. Results of path analysis on determinants of community health resilience

Dependent variable	Independent variable	Effect	Coefficient	95% CI	p-value
Community health resilience	Age	Direct	4.05	1.98 – 6.12	<0.001
Community health resilience	Sex	Direct	1.48	0.12 – 2.84	0.032
Community health resilience	Education	Direct	2.29	0.56 – 4.02	0.010
Community health resilience	Food distribution effectiveness	Direct	2.10	0.37 – 3.83	0.017
Food distribution effectiveness	Food logistics preparedness	Indirect	2.18	1.05 – 3.32	<0.001
Food distribution effectiveness	Environmental factors	Indirect	1.33	0.20 – 2.45	0.021
Food logistics preparedness	Policy support	Indirect	3.44	2.27 – 4.62	<0.001
Environmental factors	Health facilities	Indirect	1.09	0.24 – 1.95	0.012

Path analysis in this study was conducted using STATA version 13. The first stage involved model specification, which illustrates the relationships between the variables examined in the study. Figure 1 presents the conceptual specification of the path analysis model, showing the relationships between exogenous and endogenous variables. The dependent variable in this study was community health resilience. Independent variables included age, sex, education level, and the effectiveness of food distribution. In the analytical framework, food logistics preparedness, policy support, environmental factors, and health facilities were positioned as mediating variables that mediated the relationship between individual factors and community health resilience. Model identification was performed after model specification to determine the number of measured variables, endogenous variables, exogenous variables, and parameters to be estimated. In this study, there were nine measured variables, four endogenous variables, five exogenous variables, and nine parameters to be estimated. The degree of freedom (df) was calculated as follows:

Degree of freedom formula:
Df = [number of measured variables × (number of measured variables + 1) / 2] – [endogenous variables + exogenous variables + number of parameters] = 45 – 18 = 27

Path analysis can be performed when df ≥ 0. In this study, the calculated df was 27, indicating an over-identified model, meaning that path analysis could be conducted. Model fit evaluation indicated that the proposed model was consistent with the empirical data, as shown in the parameter estimation results. The theoretical model developed by the researchers was supported by the path analysis results, indicating that the model was appropriate and consistent with the computational model. The parameter estimation results are presented in Table 1.

Model respecification was conducted as the final stage of the path analysis procedure. The results showed that the model was already consistent with the sample data, as indicated by the saturated model and regression coefficients greater than zero with statistically significant values. Therefore, no further model modification was required, as the proposed model adequately represented the empirical data.

The estimation results indicate several significant relationships. First, age showed a significant positive association with community health resilience. Respondents aged >45 years had a logit score of community health resilience approximately four units higher than those aged <45 years ($b = 4.05$; 95% CI = 1.9–6.1; $p < 0.001$). Second, sex was significantly associated with community health resilience, where male respondents had a lower logit score compared with female respondents ($b = 1.4$; 95% CI = 0.12–2.84; $p = 0.032$). Third, education level showed a positive and statistically significant association with community health resilience. Respondents with higher education had a logit score approximately 2.3 units higher than those with lower education levels ($b = 2.3$; 95% CI = 0.6–4.02; $p = 0.010$).

Fourth, the effectiveness of food distribution had a positive and significant relationship with community health resilience. Respondents who experienced effective food distribution had a logit score approximately 2.1 units higher than those with ineffective distribution ($b = 2.1$; 95% CI = 0.37–3.8; $p = 0.017$). Fifth, food logistics preparedness significantly influenced food distribution effectiveness. Respondents with adequate food logistics preparedness had a logit score approximately 2.2 units higher than those without adequate preparedness ($b = 2.2$; 95% CI = 1.05–3.32; $p < 0.001$).

Sixth, environmental factors were positively associated with food distribution effectiveness. Respondents living in supportive environmental conditions had a logit score approximately 1.3 units higher than those in less supportive environments ($b = 1.3$; 95% CI = 0.20–2.5; $p = 0.021$).

Seventh, policy support significantly influenced food logistics preparedness, where respondents reporting supportive policies had a logit score approximately 3.4 units higher compared with those without policy support (b = 3.4; 95% CI = 2.27–4.62; p < 0.001). Finally, health facilities were significantly associated with environmental factors, with respondents reporting supportive health facilities having a logit score approximately 1.1 units higher than those lacking adequate facilities (b = 1.1; 95% CI = 0.24–1.95; p = 0.012).

DISCUSSION

The findings of this study indicate that community health resilience in flood-prone areas is shaped by a combination of individual, structural, and environmental factors that interact both directly and indirectly. These results emphasize that health resilience is not solely determined by individual health status, but also by the broader support systems surrounding communities, including food logistics, policy frameworks, environmental conditions, and the availability of health facilities. In disaster-prone settings, the ability of communities to maintain health and well-being depends on the integration of these multiple determinants, which together form a comprehensive resilience system capable of responding to environmental shocks and crises.

From the perspective of individual factors, age, sex, and education level were found to have direct effects on community health resilience. Older individuals tended to demonstrate stronger health resilience, which may be explained by greater life experience, improved adaptive capacity, and more mature coping strategies when facing crisis situations [22]. Although older age is often associated with increased vulnerability to chronic illness, social experience and accumulated knowledge among older individuals may strengthen collective adaptive capacity within communities. In many cases, older adults serve as sources of guidance and informal leadership during emergencies, contributing to community cohesion and collective decision-making [23]. These social roles allow older individuals to support health resilience not only through personal adaptation but also through the transmission of knowledge and experience to younger generations. Consequently, age contributes to health resilience through both biological and socio-cultural dimensions, reflecting the importance of lived experience and community engagement in disaster response [24].

Sex differences also influence community health resilience. In this study, women demonstrated higher levels of health resilience compared with men. This finding is consistent with existing literature suggesting that women often play a central role in managing household health, including food preparation, nutrition management, sanitation practices, and caregiving activities. Such responsibilities position women as key actors in maintaining family and community health during both normal and crisis conditions [25]. Women's active participation in community health activities, such as health education, maternal care, and child nutrition programs, further strengthens the capacity of households to respond to health challenges during disasters. Nevertheless, this finding also highlights the presence of gender-related vulnerabilities that require attention, particularly regarding unequal access to economic resources, decision-making authority, and healthcare services in some communities [26]. Addressing these disparities is essential to ensure that both men and women can equally contribute to and benefit from community health resilience.

Education level was another important determinant of community health resilience. Higher levels of education were associated with improved health literacy, better understanding of health risks, and greater ability to make appropriate decisions during emergency situations. Individuals with higher educational attainment are generally more capable of interpreting health information, adopting preventive behaviors, and seeking timely medical assistance when needed. Education also enhances the ability of individuals to adapt to environmental changes caused by disasters and to participate effectively in community-based disaster preparedness initiatives. In this regard, education functions as a critical empowerment mechanism that strengthens cognitive capacity, critical thinking, and problem-solving skills within communities. By improving awareness and preparedness, education ultimately contributes to the strengthening of community health resilience through informed decision-making and proactive health behavior [27].

Beyond individual characteristics, structural factors also play a crucial role in shaping community health resilience. The effectiveness of food distribution was found to have a direct influence on health resilience among communities in flood-prone areas. Effective and timely distribution of food ensures adequate nutritional intake, which is essential for maintaining immune function and reducing vulnerability to disease following disasters. In addition, equitable food distribution contributes to social stability by preventing inequalities in resource access and reducing the potential for social conflict during times of crisis. When communities perceive that resources are distributed fairly and efficiently, trust in institutions and social cohesion tend to increase, thereby strengthening collective resilience [28].

Furthermore, the effectiveness of food distribution was indirectly influenced by food logistics preparedness. Logistics preparedness encompasses several essential components, including supply planning, food storage systems, transportation infrastructure, and supply chain management. These components form the foundation of a responsive and reliable food distribution system during disaster situations [30]. Without adequate logistical preparation, food distribution may experience delays, misallocation, or wastage, ultimately undermining community health resilience. For example, disruptions in transportation routes or insufficient storage capacity may prevent essential food supplies from reaching affected populations in a timely manner. The results of this study therefore highlight the critical role of logistics preparedness as a structural determinant that supports effective food distribution and, consequently, community health resilience.

Policy support was also found to play a significant role in strengthening community health resilience through its influence on food logistics preparedness. Adaptive policies, strong inter-agency coordination, and sufficient budget allocation enable food logistics systems to function efficiently during emergency situations. Government policies that prioritize disaster preparedness and food security can facilitate rapid mobilization of resources, strengthen coordination between disaster management institutions, and ensure continuity of essential services during crises. Conversely, weak or poorly implemented policies may hinder logistical operations due to administrative barriers or limited institutional capacity. Therefore, public policy represents a key structural factor that reinforces community health resilience by supporting efficient logistics systems and coordinated disaster response mechanisms [27].

Environmental factors and health facilities also contributed indirectly to community health resilience. Supportive environmental conditions, such as adequate road infrastructure, reliable transportation networks, and favorable geographic accessibility, enhance the effectiveness of food distribution and facilitate access to healthcare services [18]. In contrast, environmental barriers such as damaged roads, isolated locations, or limited transportation infrastructure can significantly hinder the delivery of food supplies and medical assistance in disaster-affected areas. These environmental constraints may prolong recovery processes and increase health risks among affected populations.

Health facilities play a complementary role in this context. Adequate health facilities not only provide essential medical services but also function as important centers for health information dissemination, disease surveillance, and emergency response coordination. During disasters, health facilities often become focal points for community support, offering preventive services, treatment, and public health guidance. The interaction between supportive environmental conditions and accessible health facilities creates a synergistic effect that strengthens overall community health resilience. When health systems operate effectively within supportive environmental contexts, communities are better equipped to manage health risks, recover from disasters, and maintain well-being in the long term [29].

Overall, the findings of this study demonstrate that community health resilience is the result of complex interactions among individual, structural, and environmental determinants. Individual factors such as age, sex, and education directly influence the capacity of individuals to respond to health challenges, while structural and environmental factors reinforce this capacity through indirect pathways. Consequently, efforts to strengthen community health resilience in flood-prone areas require an integrated and multisectoral approach. Such efforts should not focus solely on improving individual health behaviors, but also on strengthening food logistics systems, enhancing policy support, improving environmental infrastructure, and expanding access to health facilities. By addressing these interconnected determinants simultaneously, communities will be better prepared to withstand and recover from the health impacts of flooding and other natural disasters.

CONCLUSION

Overall, the findings of this study indicate that community health resilience is influenced by individual factors (age, sex, and education), structural factors (food distribution effectiveness, logistics preparedness, and policy support), and environmental factors (infrastructure and health facilities). The interaction among these factors suggests that community health resilience results from a combination of individual capacities, systemic support, and environmental conditions.

Ethical consideration, competing interest and source of funding

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