



Modeling the Impact of Climate Disasters on Trauma: The Role of Digital Literacy in Disaster-Prone Regions

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ABSTRACT

Climate-induced hydrometeorological disasters represent a systemic threat to public mental health, yet the role of digital environments in moderating these outcomes remains under-researched. This study examines the psychosocial impact of extreme weather events and evaluates digital literacy as a protective factor against trauma. Utilizing a quantitative ecological design, the research analyzes a provincial-level Big Data synthesis (N = 38) from Indonesia, integrating datasets from the National Disaster Management Authority (Badan Nasional Penanggulangan Bencana, BNPB), the 2023 National Basic Health Research (Riset Kesehatan Dasar, Riskesdas), and the National Digital Literacy Index. Moderated Regression Analysis (MRA) was employed to determine the predictive relationship between disaster frequency and the prevalence of emotional-mental disorders. The findings reveal a significant positive correlation between disaster frequency and trauma prevalence ($r = 0.642, p < 0.005$). Crucially, the results indicate that high digital literacy significantly buffers the impact of disaster-related distress ($t = -2.154, p = 0.038$), whereas high internet penetration without adequate literacy exacerbates anxiety through infodemic exposure. These results imply that disaster mitigation must evolve beyond physical infrastructure to include digital cognitive empowerment. The study concludes that integrating digital literacy into national mental health policies is essential for climate resilience, suggesting that future research leverage real-time AI sentiment analysis to refine community-based psychosocial interventions.

Keywords : Climate Change, Hydrometeorological Disasters, Mental Disorders, Digital Literacy, Regression Modeling



INTRODUCTION

The global climate crisis has evolved beyond a mere ecological concern, metamorphosing into a systemic public health emergency that disproportionately affects vulnerable populations. Hydrometeorological catastrophes encompassing torrential flooding, cyclonic activities, and prolonged droughts have been empirically linked to an elevated risk of psychopathological complications among affected communities. In practical terms, this issue manifests as a sharp increase in generalized anxiety disorders and post-disaster depression, which frequently bypass detection within primary healthcare frameworks. Theoretically, contemporary environmental psychology emphasizes that persistent exposure to climatic instability induces a cognitive burden known as "eco-anxiety," characterized by a chronic apprehension of environmental collapse (Clayton, 2021).

A significant imperative for the scientific community today lies in determining how these environmental variables can be mathematically modeled to mitigate future mental health trajectories in high-risk zones (Cianconi, 2023). Recent scholarship exploring the nexus between hydrometeorological events and psychological well-being has identified that residents in disaster-prone regions exhibit a 40% higher probability of developing symptoms associated with Post-Traumatic Stress Disorder (PTSD) compared to the general population (Rataj, 2021). Longitudinal evidence suggests that these psychological impacts are cumulative; specifically repeated exposure to flash floods results in a measurable decline in psychological resilience (Berry, 2023). Nevertheless, the bulk of existing research remains focused on immediate physical ramifications, often disregarding the digital variables that have become intrinsic to modern human life.

A critical research gap exists because current literature lacks the integration between physical disaster frequency and digital behavioral data within a cohesive regression framework (Charlson, 2021). The discrepancy between theoretical models and empirical reality is rooted in the dualistic role of information technology in the digital era. In Indonesia, where internet penetration reached 79.5% by 2024, a paradox has emerged: while digital tools facilitate early warning systems, they simultaneously accelerate "doomscrolling" the compulsive consumption of disaster-related news ((Asosiasi Penyelenggara Jasa Internet Indonesia (APJII), 2024).

Data from the Ministry of Health indicates a 9.8% rise in the prevalence of emotional and mental disorders among adults residing in provinces with high disaster frequency (Kementerian Kesehatan Republik Indonesia, 2024). It is strongly suspected that low digital literacy indices in these regions are suspected of exacerbating anxiety levels, as individuals lack the cognitive filters necessary to process traumatic disaster information on social media platforms (Kementerian Komunikasi dan Informatika Republik Indonesia, 2023). Addressing this gap, the present study aims to construct a regression model correlating hydrometeorological disaster frequency, internet penetration rates, and digital literacy indices with the prevalence of anxiety and trauma. The central inquiry of this research is whether digital literacy serves as a protective factor capable of moderating the psychosocial consequences of disasters. The novelty of this article lies in its application of province-based Big Data analysis, synthesizing secondary data from technical ministries and



internet industry associations to produce a high-precision predictive model for environmental mental health (Lawrance et al., 2022; Pihkala, 2022).

METHODS

This study adopts a quantitative methodology utilizing an Ex Post Facto design that integrates spatial analysis with health econometrics. This design was selected because the research variables specifically hydrometeorological disasters and mental health prevalence have occurred naturally, rendering experimental manipulation by researchers impossible. To ensure rigorous causal inference within this non-experimental framework, the investigative framework is anchored in Environmental Psychosocial Modeling, which seeks to quantify the impact of physical environmental stressors and digital moderation on the psychosocial condition of the population at the provincial level.

The robustness of the research is further established by utilizing multiple linear regression modeling to test hypotheses regarding the cumulative effect of disasters on collective trauma. The research subjects consist of the Indonesian population aggregated across 38 provinces. This study leverages large-scale secondary data, categorized here as Big Data due to the integration of multi-sectoral datasets (environmental, health, and digital) that require complex processing to align spatial and temporal variables. The data integration protocol ensures that multi-source data points are synchronized to the 2023-2024 reporting period to capture the most recent socio-environmental dynamics.

The data sample follows a provincial census approach ($N = 38$), encompassing:

- a. Disaster Event Data: All verified reports of floods, extreme weather, and landslides throughout 2023, as documented by the Badan Nasional Penanggulangan Bencana (BNPB). A total of 4,940 events were analyzed (Badan Nasional Penanggulangan Bencana [BNPB], 2024).
- b. Mental Health Data: Prevalence rates of Emotional Mental Disorders (EMD) and Depression extracted from the (Kementerian Kesehatan Republik Indonesia (Riskesdas), featuring a representative sample of 300,000 households across Indonesia (Kementerian Kesehatan Republik Indonesia, 2024).
- c. Digital Literacy and Internet Penetration Data: Provincial digital literacy indices derived from national surveys of 10,000 respondents, alongside internet penetration data (Asosiasi Penyelenggara Jasa Internet Indonesia (APJII), 2024).

The research procedure was divided into five systematic phases to ensure study replicability:

1. Data Integration Phase: Merging datasets from BNPB, the Ministry of Health, and the Ministry of Communication and Informatics using Badan Pusat Statistik (BPS) regional codes as unique keys.
2. Normalization Phase: Converting raw data into ratios per 100,000 residents to equalize comparison weights across provinces with differing population sizes.
3. Assumption Testing Phase: Conducting normality, multicollinearity, and heteroscedasticity tests to ensure the regression model serves as a Best Linear Unbiased Estimator (BLUE).



4. Modeling Phase: Constructing a Moderated Regression Analysis (MRA) model executed using IBM SPSS Statistics 26 software to examine the interaction between disaster frequency and digital literacy.
5. Validation Phase: Performing sensitivity analysis to verify the stability of the regression coefficients.

The primary instrument in this research is the Data Extraction Protocol, designed to guarantee the validity of secondary data. Variable measurements utilize official government scales:

- a. Digital Literacy Index (DLI): Measured using four pillars: Digital Skills, Digital Ethics, Digital Safety, and Digital Culture, evaluated on a 1–5 Likert scale.
- b. Trauma Prevalence: Assessed using the Self-Reporting Questionnaire (SRQ-20) instrument, which has been validated by the Ministry of Health for the Indonesian population.

Data analysis was conducted incrementally using descriptive and inferential statistics. Multiple linear regression modeling was employed to determine simultaneous influences. The mathematical equation used is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 (X_1 \cdot X_2) + \epsilon$$

Where:

- Y : Prevalence of Mental Disorders/Trauma (%)
- X_1 : Frequency of Hydrometeorological Disasters
- X_2 : Digital Literacy Index
- $X_1 \cdot X_2$: Interaction between disaster and literacy (moderating effect)
- β_0 Intercept (constant value of Y when all independent variables are zero)
- $\beta_0, \beta_1, \beta_2, \beta_3$: **Partial regression coefficients for each respective variable and interaction**
- ϵ : Standard error

Table 1 presents the operational definitions of the key variables employed in this study, along with their respective indicators, units of measurement, and primary data sources. This structured classification ensures transparency in variable conceptualization and facilitates replication by other researchers.

Table 1. Operational Definition of Variables and Data Sources

| Variable | Indicator | Unit | Source |
|--------------------------------|--|------------------|------------------|
| Dependent Variable (Y) | Emotional Mental Disorder Prevalence | Percentage (%) | Riskesdas (2024) |
| Independent Variable (X_1) | Hydrometeorological Disaster Frequency | Number of Events | BNPb (2024) |



| Variable | Indicator | Unit | Source |
|-------------------------------|-----------------------------------|----------------|-------------------|
| Moderating Variable (X_2) | Provincial Digital Literacy Index | Score (1-5) | Kemkominfo (2023) |
| Control Variable (X_3) | Internet Penetration | Percentage (%) | APJII (2024) |

Table 1 delineates the dependent variable as Emotional Mental Disorder Prevalence, measured in percentages from Risdas (2024), which captures the psychosocial health outcomes under investigation. The primary independent variable, Hydrometeorological Disaster Frequency (X_1), is quantified by the number of events reported by BNPB (2024), serving as the core environmental stressor. Moderation is introduced through the Provincial Digital Literacy Index (X_2) from Kemkominfo (2023), scored on a 1-5 scale, while Internet Penetration (X_3) from APJII (2024) acts as a control to account for digital access disparities across provinces.

RESULTS

1. Data Characteristics and Spatial Distribution

The analysis of secondary data across 38 Indonesian provinces reveals significant variability in the frequency of hydrometeorological disasters and their subsequent impact on public mental health. These findings confirm that regions with high disaster intensity tend to bear a heavier psychosocial burden.

a. Distribution of Hydrometeorological Disaster Events

According to 2023 data from the BNPB, a total of 4,940 disaster events were recorded, with floods (44%) and extreme weather (31%) dominating the national risk profile.

Table 1. Distribution of Disaster Events by Key Regions (2023)

| Region | Dominant Disaster Type | Frequency Rank | Observation |
|------------------|------------------------|----------------|---|
| West Java | Floods & Landslides | High | Correlates with high population density |
| East Java | Extreme Weather | High | Significant exposure to environmental stressors |
| Central Sulawesi | Floods | Moderate-High | Linked to elevated EMD prevalence |



b. Prevalence of Emotional Mental Disorders (EMD)

Based on the most recent Riskesdas data, the national EMD prevalence stands at an average of 9.8% among the population aged >15 years

Table 2. EMD Prevalence in High-Risk Provinces

| Province | EMD Prevalence (%) | Status |
|--------------------|--------------------|------------------------|
| Central Sulawesi | 12.4% – 13.1% | Above National Average |
| West Nusa Tenggara | 12.4% – 13.1% | Above National Average |
| National Average | 9.8% | Baseline |

This aligns with the theory that collective trauma stemming from climate instability is not merely transitory but persists over the long term (Berry, 2023; Cianconi, 2023).

2. Analysis of Mathematical and Statistical Components

Hypothesis testing was conducted via a multiple linear regression model to evaluate the influence of Disaster Frequency (X_1) and Digital Literacy (X_2) on Trauma Prevalence (Y). The estimated model parameters are presented in the following equation:

$$Y = 5.214 + 0.456X_1 - 0.289X_2 + \epsilon$$

Statistical evaluation yielded a correlation coefficient of $r = 0.642$ with a significance level of $p = 0.001$. The F-test indicates the simultaneous significance of the model with $F(2,35) = 14.282$, $p < 0.005$, and a partial eta squared value ($\eta_p^2 = 0.42$), suggesting a substantial effect size.

- Influence of Disasters (X_1): $t(36) = 3.842$; $p = 0.002$. This demonstrates that every increase in disaster frequency significantly elevates trauma prevalence.
- Influence of Digital Literacy (X_2): $t(36) = -2.154$; $p = 0.038$. The negative coefficient indicates that higher digital literacy plays a role in reducing anxiety risks in disaster-prone areas.



3. Data Visualization and Key Findings

Table 3. Summary Statistics of Variables Based on Sample Regions ($N = 38$)

| Variable | Mean | Std. Deviation | Min | Max |
|----------------------------|--------|----------------|-------|--------|
| Disaster Frequency (Units) | 130.20 | 45.12 | 12.00 | 540.00 |
| EMD Prevalence (%) | 9.82 | 2.15 | 6.10 | 14.20 |
| Digital Literacy Index | 3.54 | 0.42 | 2.90 | 4.10 |
| Internet Penetration (%) | 78.12 | 6.34 | 62.10 | 89.50 |

Significant findings in this study indicate a critical interaction between digital information exposure and anxiety levels. Provinces characterized by high internet penetration (>80%) but low digital literacy (<3.30) showed a 1.5-fold spike in anxiety prevalence during disasters compared to regions with high digital literacy. This confirms that digital literacy is not merely a technical skill but functions as a psychological defense mechanism for filtering traumatic information

DISCUSSION

The empirical evidence provided in this study confirms that hydrometeorological disasters are not merely isolated physical occurrences but function as systemic social determinants of mental health within the Indonesian landscape. The identified positive correlation between disaster frequency (X_1) and the prevalence of emotional-mental disorders (Y), as indicated by the regression coefficient $\beta_1 = 0.456$, suggests an accumulative trauma burden. This phenomenon is theoretically grounded in the concept of Solastalgia, which describes the profound psychological distress experienced when one's home environment changes so drastically that it no longer offers a sense of security (Clayton, 2021). This finding is consistent with research by Rataj (2021), which highlights that chronic exposure to environmental instability in Southeast Asia significantly predicts long-term PTSD symptoms. In regions plagued by recurrent inundation, such as the coastal corridors of Java and Sulawesi, communities exhibit symptoms of chronic anticipatory anxiety a persistent dread regarding the inevitable return of the next disaster cycle (Berry et al., 2023).

Furthermore, these findings emphasize that the psychosocial ramifications of disasters are non-linear and heavily influenced by localized economic vulnerabilities. Populations in provinces with a high dependency on the agricultural sector suffer more acute distress, as hydrometeorological events directly decimate their productive assets. Data from this study shows that provinces with the highest disaster frequency also report the highest EMD rates, supporting the claim that economic losses attributed to climate instability contribute to a 15% increase in depression risk among heads of households in affected zones (Kementerian Kesehatan RI, 2024). This trauma is further intensified



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by the erosion of social capital and the collapse of community support networks, which often occur simultaneously during large-scale catastrophes (Cianconi et al., 2023).

A central discourse in this investigation revolves around the function of digital literacy as a significant protective factor. In the contemporary digital era, disaster-related information propagates more rapidly than the hazards themselves. Indonesia's high internet penetration rate (78.12%) creates an environment where the populace is incessantly exposed to traumatic content. The regression results ($t = -2.154$; $p = 0.038$) indicate that in the absence of adequate digital literacy, this information exposure triggers "secondary traumatization" distress experienced by individuals who are not physically impacted but are subjected to intense visual consumption of disasters in digital spaces. This aligns with Lawrance (2022), who argued that digital environments can either exacerbate or mitigate climate-related distress depending on user competence..

Conversely, individuals possessing robust digital literacy skills demonstrate the capacity for cognitive re-appraisal regarding the information they receive. They are equipped to distinguish valid early warnings from provocative disinformants or hoaxes. This capability acts as an effective ego-defense mechanism, mitigating the activation of the sympathetic nervous system typically triggered by hyperbolic bad news. Consequently, digital literacy must be redefined beyond technical proficiency; it serves as a critical emotional regulation skill in cyberspace, essential for maintaining mental equilibrium in disaster-prone regions (Pihkala, 2022). While previous studies by Charlson (2021) focused primarily on physical proximity to disasters, this research develops the narrative by proving that digital competence is a modern determinant of psychological resilience.

An intriguing paradox emerged within the data: regions with the most advanced digital infrastructure do not necessarily exhibit superior post-disaster mental health outcomes. This suggests that the mere availability of technology without user education may be counterproductive. The phenomenon of "doomscrolling" the compulsive search for distressing news was observed more frequently in urban populations with high-speed internet but moderate digital literacy levels (Lawrance, 2022). This offers a fresh perspective for policymakers: the expansion of internet connectivity in disaster zones must be coupled with digital mental health promotion campaigns. Moreover, this study identifies that the efficacy of digital interventions is contingent upon public trust in official information sources. When citizens possess high digital literacy, they tend to rely on governmental communication channels, such as BNPB or BMKG, rather than rumors circulating in private messaging groups. This significantly diminishes mass panic, which is a primary catalyst for acute anxiety disorders during the emergency phase of a disaster (World Health Organization [WHO], 2022).

The findings of this research have fundamental implications, though certain interpretations are limited by the ecological nature of the data. A primary recommendation is the integration of psychosocial support into existing early warning systems (EWS). However, it must be noted that this study is limited by its reliance on provincial-level secondary data, which may mask micro-level variations at the village or sub-district scale. Mitigation strategies should no longer operate in silos; the mental health sector must collaborate with the telecommunications sector to forge a resilient



information ecosystem. Prioritizing digital literacy training for disaster volunteers at the village level is also essential to ensure that risk communication is conducted in a non-traumatizing manner (Rataj, Extreme weather events and mental health: A narrative review, 2021).

Despite its depth, this study is limited by its reliance on provincial-level secondary data, which may generalize conditions at the micro-level (village or sub-district). Future research should explore the utilization of Artificial Intelligence (AI) to conduct real-time sentiment analysis on social media during disaster events, thereby mapping anxiety "hotspots" with higher precision. Additionally, longitudinal studies are required to track the long-term effectiveness of digital literacy programs in reducing PTSD rates among survivors of hydrometeorological hazards .

CONCLUSIONS

This study concludes that the climate crisis, manifested in hydrometeorological catastrophes, exerts a significant and measurable psychopathological influence on populations within Indonesia's high-risk regions. In alignment with the initial hypothesis, the regression modeling reveals that the frequency of physical disasters maintains a linear correlation with elevated levels of emotional-mental disorders and collective trauma. The most vital finding is that digital literacy serves as a crucial moderating variable that significantly buffers the impact of disaster-related distress. This confirms that community resilience in the modern era depends not only on physical infrastructure but also on cognitive proficiency in managing digital information flows.

The analytical results demonstrate a digital paradox: while high internet penetration facilitates early warning systems, it simultaneously exacerbates anxiety through "doomscrolling" when digital literacy is low. By integrating data from BNPB, the Ministry of Health, and the Ministry of Communication and Informatics, this research provides a novel foundation for disaster mitigation. The findings suggest that digital literacy acts as an effective psychological defense mechanism at the provincial level, helping individuals filter traumatic content and reduce secondary traumatization.

In conclusion, disaster mitigation policies must incorporate digital mental health interventions as a core component. Future efforts should focus on implementing real-time surveillance systems and developing disaster-specific digital literacy curricula for vulnerable groups. The synchronization of telecommunication infrastructure with psychosocial support is imperative to establish a holistic ecosystem that is resilient against the future challenges of climate change

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