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RISK PRODUCTION AND URBAN VULNERABILITY IN CONAKRY: INTEGRATING GOVERNANCE, LAND USE, AND BIOPHYSICAL FACTORS IN THE 2025 MANÉAH LANDSLIDE

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Background: Rapid urbanization in West Africa increasingly exposes populations to hazard-prone areas. The Manéah landslide (Conakry, Guinea, 2025) exemplifies the Anthropocene dynamic, where human decisions, governance failures, and unregulated urban expansion convert biophysical hazards into disasters, disproportionately affecting informal sector workers and residents on unstable slopes. Understanding these interactions is critical for risk-informed urban planning and environmental management. **Objectives**: This study aimed to identify systemic drivers of urban landslide risk in Manéah, integrating biophysical conditions, urban infrastructure, governance mechanisms, and social vulnerability, to provide empirically grounded insights for transformative resilience and disaster risk reduction. **Methods**: A mixed, sequential methodology was employed. Post-disaster fieldwork included a seven-day systematic survey of slope instability, GPS mapping, UAV imagery, and photographic documentation. A socio-economic survey (n=62) captured household losses, income disruption, and recovery expectations. Documentary analysis of ESIA and ESMP reports evaluated compliance and institutional oversight. Quantitative data were analysed using chi-square and Fisher's exact tests in R, while qualitative data were coded thematically. Spatial analyses employed QGIS, generating slope and hazard maps. Triangulation of field observations, socio-economic responses, and institutional documentation allowed reconstruction of systemic risk drivers and identification of governance and social vulnerabilities amplifying disaster impacts. **Results**: Results reveal that informal sector workers and households on unstable slopes bore the greatest losses, with 95–100% reporting income disruption, while civil servants exhibited higher resilience due to formal employment. Directly affected persons overwhelmingly preferred permanent relocation (92%), whereas displaced households favoured return after stabilization (85%), confirmed by statistically significant chi-square and Fisher's exact tests. The odds ratio of 242 indicates a stark divergence in recovery aspirations. ESIA and ESMP implementation was largely absent, illustrating governance deficits. Fragmented responsibilities among construction companies and weak regulatory enforcement amplified risk. Overall, disaster impacts were determined more by cumulative governance failures and social vulnerability than by biophysical hazards alone, highlighting structural inequalities. **Conclusion**: The Manéah landslide demonstrates that urban disasters in West Africa are driven by governance failures and social inequities, not exclusively by natural hazards. Effective risk mitigation requires integrating political, ethical, and community-based approaches into urban planning and resilience strategies.

Keywords: landslide, environmental risk, vulnerability, disaster risk reduction, socio-economic impact analysis, environmental management, sustainable development, urban planning, early warning system.

INTRODUCTION

The recurrence and intensification of so-called "natural" disasters is a prominent marker of the Anthropocene, a geological epoch in which human activity has become a dominant force shaping Earth's systems (Crutzen, 2002; Steffen et al., 2015). In West Africa, this trend is evident in the increasing frequency and severity of floods and landslides during the rainy season (June–September) (Tarchiani et al., 2021). Guinea, endowed with significant natural resources but undergoing rapid and often unplanned urbanization, extensive deforestation, and accelerated infrastructure development, exemplifies the intersection of environmental vulnerability and human pressures. In Conakry, the capital, over 50% of the population resides in informal settlements, frequently located on steep, unstable slopes or in flood-prone areas, increasing exposure to landslide and slope instability risks (SOS Villages d'Enfants, 2025).

On 20 August 2025, a translational landslide on Mount Kakoulima in the commune of Manéah caused 27 fatalities and significant material damage. While official reports attributed the event primarily to exceptional rainfall, field observations reveal substantial anthropogenic influence, including slope cuts for road construction, borrow pits, and unregulated building on unstable terrain. These human-induced modifications appear to have altered slope stability conditions and increased local susceptibility to failure, particularly in zones already characterized by geomorphological fragility. The spatial coincidence between infrastructural interventions and the failure zone further suggests a non-random distribution of triggering factors. This event thus represents a convergence of biophysical susceptibility, urban planning deficiencies, and environmental governance gaps, creating a systemic risk situation.

Despite increasing urban landslide occurrences in sub-Saharan Africa, the mechanisms through which interactions between infrastructure development, land-use planning, and governance failures amplify risk remain insufficiently documented. In many rapidly urbanizing contexts, hazard processes are increasingly shaped by cumulative and often informal modifications of the terrain rather than by purely natural triggers. Understanding these mechanisms is therefore critical for risk-informed urban planning and environmental engineering interventions that aim to reduce future exposure and vulnerability.

This study addresses this gap by examining the Manéah landslide through an integrated analysis of biophysical conditions, public policy, land-use practices, and local perceptions. The central research question is: To what extent can the Manéah disaster be understood as the product of accumulated failures in environmental and urban governance, and what insights does it provide for improving risk management in rapidly urbanizing African cities?

By explicitly linking urban vulnerability, environmental processes, and policy failures, this work situates the Manéah case within the broader context of risk-sensitive urban studies, offering insights relevant for environmental engineering, hazard mitigation, and sustainable urban development in sub-Saharan Africa.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The Anthropocene and urban hazard dynamics

The concept of the Anthropocene emphasizes that human activities are now the primary drivers shaping Earth's systems (Crutzen, 2002; Luciano, 2022). Contemporary reviews further highlight that the Anthropocene concept explains how humanity has become the dominant force behind profound changes in climate, the biosphere, and land use on a global scale (Zalasiewicz et al., 2020; Little et al., 2023). Within this framework, hazards such as intense rainfall, slope instability, or floods are transformed into disasters largely through human decisions, including urban expansion, infrastructure development, and land-use management (Clark & Yusoff, 2017; Orozco, 2020). Understanding this transformation is essential for risk-informed environmental engineering and urban planning, particularly in the rapidly urbanizing contexts of sub-Saharan Africa.

Environmental and urban governance

Urban disaster risk is significantly influenced by governance structures and planning practices (Galasso et al., 2021; Menoni, 2025). Environmental sociology underscores that risk is socially constructed, reflecting inequalities in exposure, capacity to cope, and decision-making power (Douglas & Wildavsky, 1982; Beck, 1992; Xiao et al., 2022; Ozturk et al., 2025). In African cities, governance gaps frequently manifest in the form of unregulated construction on steep slopes (Dodman et al., 2017), inadequate zoning, and weak enforcement of environmental impact assessments (ESIAs), thereby creating systemic vulnerabilities (Felli & Castree, 2012; Leck et al., 2018). Despite these insights, empirical research that integrates governance analysis with ecological and physical assessments of urban landslide risk remains limited (Wachinger et al., 2013; Maes et al., 2017; Jacobs et al., 2016; Maes, 2018).

Risk production and environmental engineering perspective

According to the classical model, disaster risk is understood as a function of both hazard and vulnerability (UNDRR, 2015); however, this conceptualization does not fully capture the processual and cumulative nature of urban disaster risk. The concept of "risk production" emphasizes that repeated decisions related to land use, infrastructure development, and resource management progressively increase exposure to known hazards (Hewitt, 1983; Birkmann et al., 2010), thereby shaping the spatial and socio-economic distribution of risk. This perspective has been further elaborated in critiques of risk creation through development decisions (Muir & Opdyke, 2024), as well as in analyses demonstrating how unplanned urbanization actively generates and amplifies disaster risk (Poudel et al., 2023). Such processes often operate incrementally and may remain unnoticed until a triggering event reveals their cumulative impact. In this context, engineering approaches provide essential quantitative tools for identifying thresholds of instability and assessing the physical conditions under which failure becomes likely. When this framework is integrated with biophysical and engineering analyses, including soil characteristics, slope gradients, and hydrological triggers, it enables a more holistic understanding of landslide risk in urban environments.

Transformative resilience

Resilience frameworks provide an important lens for assessing not only the capacity to recover from hazards but also the potential to transform urban systems in ways that reduce vulnerability (Pelling, 2011; Meerow et al., 2016; Ribeiro et al., 2019; Amirzadeh et al., 2022). In particular, transformative resilience addresses structural factors such as land tenure, infrastructure development practices, and governance mechanisms that contribute to social and environmental vulnerability (Hölscher & Frantzeskaki, 2021). Although this perspective is increasingly applied in sub-Saharan Africa, empirical studies that link transformative resilience with measurable ecological and engineering factors remain scarce (Leck et al., 2018; Tinega et al., 2025; Mensah & Yankson, 2025).

Despite the growing attention to urban disasters in sub-Saharan Africa, relatively few studies combine biophysical assessments, infrastructure and planning analysis, governance evaluation, and social vulnerability data in order to examine the mechanisms driving landslide risk. Most existing research tends to focus either on physical hazard modelling or on social vulnerability (McPhearson et al., 2016), and only rarely integrates these perspectives into actionable recommendations for risk-informed urban planning and environmental engineering (McPhearson et al., 2016; Meerow et al., 2016). This fragmentation of approaches limits the ability to identify systemic drivers of risk and to develop comprehensive mitigation strategies.

This study addresses this gap by examining the Manéah landslide (Conakry, Guinea) through an integrated analysis of biophysical conditions (soils, slope, rainfall), infrastructure and urban planning practices (land-use, road construction, ESIA compliance), and governance structures alongside social vulnerability (local perceptions, institutional capacity). The objective is to identify systemic drivers of urban landslide risk and to provide empirically grounded insights for improving environmental management and hazard mitigation in rapidly urbanizing African cities.

In line with this integrated approach, the study advances the following hypotheses, which directly reflect the interplay between social vulnerability, physical impacts, and governance conditions discussed above. First, socio-economic vulnerability is disproportionately concentrated among informal sector workers, resulting in higher income loss compared to formal sector employees. Second, total housing loss leads to significantly lower resilience scores than partial loss, reflecting the cumulative impact of structural and social disruption. Third, directly affected households tend to prefer permanent relocation, whereas displaced households are more likely to return, indicating that trauma and perceived site safety shape recovery decisions. Finally, urban landslide risk in Manéah is driven primarily by failures in environmental governance, including unimplemented ESIA/ESMP measures and fragmented oversight, rather than being caused exclusively by natural hazards.

MATERIALS AND METHODS

Study area

Geographic location and topography

The study was conducted in the urban commune of Manéah (Figure 1), integrated into the capital city of Conakry, Guinea, following administrative restructuring in 2024 (MATD, 2024). The approximate centre of the landslide-affected zone is located at 9°45′05.1″ N, 13°26′11.5″ W. The commune spans approximately 350 km² and is dominated by the Mount Kakoulima massif, with a maximum elevation of 1,007 m.

Slope gradients vary with geomorphological position: the north-western flank above the landslide rupture zone exhibits slopes >30%, mid-slopes range from 15–30%, and the southern and eastern coastal plains have slopes <5%. Such variability aligns with topographic characterizations reported in the ESIA for the Kagbélen–Kouria road project (WEST Ingénierie SARL, 2022). Coastal plains, underlain by recent deltaic deposits, are generally stable regarding slope failure but remain prone to seasonal flooding.

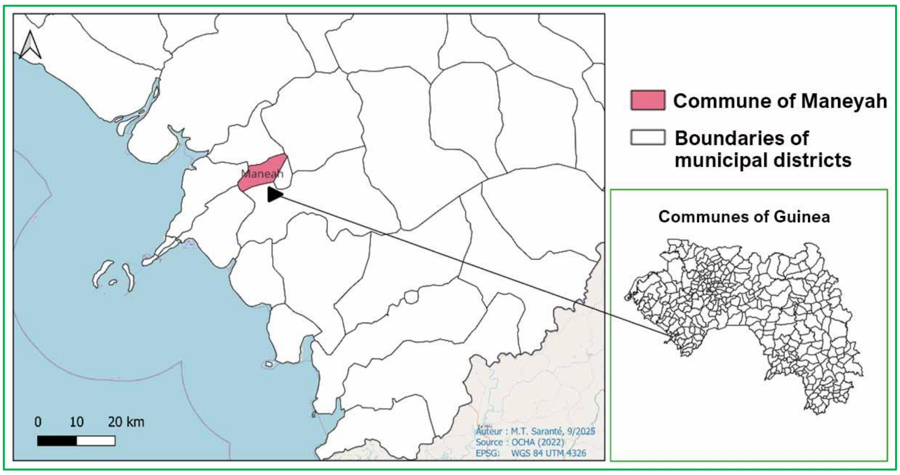

Figure 1. Map of the landslide-affected study area

Geology and soils

The geological substrate of the study area is primarily composed of Paleozoic sedimentary formations, including sandstones and schists, which constitute the structural basement of the Mount Kakoulima massif. These lithologies have undergone extensive chemical weathering under the prevailing hot and humid tropical conditions, resulting in the formation of a thick lateritic regolith that blankets much of the slope system (Grange, 1961; WEST Ingénierie SARL, 2022). This regolith plays a critical role in slope stability, acting both as a weathered protective mantle and a material prone to saturation-induced weakening.

Soil cover in the study area is dominated by Ferralsols and Acrisols, as classified according to the World Reference Base for Soil Resources (WRB) system (IUSS Working Group WRB, 2022). Ferralsols are intensely weathered soils, enriched in iron and aluminium oxides, with a predominantly clay-rich matrix characteristic of tropical environments. Acrisols, commonly found on mid- to lower-slope positions, display pronounced subsurface clay accumulation and low base saturation.

Both soil types are associated with high water retention capacity; however, their geotechnical behaviour is highly sensitive to moisture variations. Upon saturation, the soils exhibit a marked reduction in effective cohesion (c′), leading to substantial decreases in shear strength and heightened susceptibility to slope failure under prolonged or intense rainfall events (Leprun, 1979; Ayalew & Yamagishi, 2005). This behaviour is particularly critical on steep slopes and foot slope positions, where water accumulation and lateral seepage exacerbate destabilization.

The Environmental and Social Impact Assessment (ESIA) for the Kagbélen–Kouria road project corroborates these observations, describing the lateritic materials as structurally weak and highly sensitive at slope foot positions (WEST Ingénierie SARL, 2022). Such documented vulnerability underscores the pre-existing recognition of slope instability, providing a critical context for understanding landslide susceptibility in the area.

Climate and rainfall

The study area has a sub-Guinean climate with a rainy season from May to November and a dry season from mid-November to early May. Mean annual precipitation ranges from 3,000 to 4,000 mm, peaking in July–August (World Bank Climate Change Knowledge Portal, 2025). Such high rainfall totals are widely recognized as a primary driver of slope instability in tropical environments. The marked seasonality of precipitation also leads to pronounced contrasts in soil moisture conditions between wet and dry periods, which may further influence slope mechanical behaviour over time. In addition, repeated high-intensity rainfall events contribute to progressive weakening of weathered materials and reduce the overall stability threshold of hillslopes.

In the 72 hours preceding the landslide on August 20, 2025, locally recorded rainfall, unpublished but consistent with National Meteorological Agency records, exceeded 300 mm, significantly above typical daily maxima. Such intense rainfall likely triggered slope failure by saturating the lateritic regolith, increasing pore-water pressures, and reducing effective stress to critical levels. Rapid infiltration under already elevated antecedent moisture conditions may have further accelerated the transition to failure. The temporal concentration of rainfall suggests a short-duration but high-impact hydrometeorological trigger acting on a preconditioned slope system.

Population and land use

Manéah has 232,736 inhabitants, including 118,603 women, with 2.3% annual growth (RGPH 4, 2025). Rapid urbanization has driven informal settlements to occupy hazard-prone lands, including steep slopes and drainage pathways. The local population relies predominantly on informal livelihoods (agriculture, livestock, trade, artisanal transport, and fishing), increasing vulnerability to environmental shocks (Pelling, 2011; Wisner et al., 2004).

Slope assessment methodology

Field measurements

Slope gradients were measured during a post-disaster reconnaissance in September 2025 at 15 representative

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locations using a handheld Suunto clinometer (±1° accuracy). Measurement points were georeferenced with GPS. Field data were cross-validated against topographic maps and ESIA data (WEST Ingénierie SARL, 2022).

Integration with remote sensing

High-resolution satellite imagery and UAV surveys were integrated to enhance spatial accuracy and capture slope variability (Giardina et al., 2024; Mertens et al., 2025). UAV flights used a DJI Mavic 3E with RTK positioning, processed in Agisoft Metashape 2.0 to generate orthomosaics and digital surface models (DSMs). Field GPS points were used for georeferencing validation. In the context of lateritic soil systems, such combined approaches are particularly important for capturing spatial variability in slope conditions and improving slope stability assessments (Ozturk et al., 2025).

Socio-economic survey

A socio-economic survey was conducted in September 2025 to assess the impacts of the Manéah landslide on affected communities and stakeholders. The survey was carried out in three locations: (i) Fragafily, the landslide epicentre (Figure 2); (ii) the town hall of Manéah, where administrative authorities were interviewed; and (iii) the Manéah military school, which served as a temporary relocation site for households evacuated from high-risk zones.

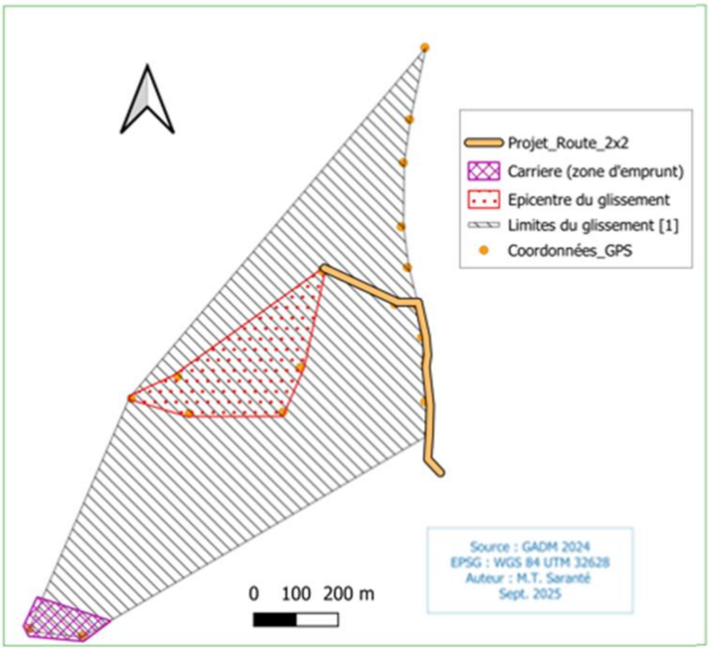

Figure 2. Map of the landslide area

The questionnaire was developed and subsequently validated by the Environmental Committee established to coordinate the landslide response. This inter-ministerial committee, led by the Office of the Minister of Environment, included representatives from the ministries of Environment, Higher Education, Geology, Health, Public Works, Transport, and Housing and Land Use Planning. Validation focused on content relevance, clarity, and contextual appropriateness.

A purposive sampling strategy was adopted to ensure inclusion of key stakeholder groups directly or indirectly affected by the landslide. To improve balance across groups, predefined quotas were applied to four categories: (i) households whose primary residence was partially or completely destroyed; (ii) individuals displaced from the orange zone (evacuated areas with structurally intact housing); (iii) local and administrative authorities involved in urban planning, environmental management, or disaster response; and (iv) workers engaged in infrastructure projects within the affected area. Recruitment was conducted in collaboration with local authorities, neighbourhood leaders, and community-based organizations.

A total of 62 respondents were surveyed, including directly affected persons, displaced persons, local authorities, and construction workers. The distribution by category is presented in Table 1. Participant characteristics, disaster impacts, and resilience indices are summarized in Table 3 in the Results section. Percentages were calculated relative to the total sample (n = 62). Due to the non-probability sampling design, sampling error could not be estimated; therefore, results are reported as descriptive statistics without inferential generalization.

The questionnaire included both closed-ended and open-ended items addressing material losses, income disruption, risk perception, coping strategies, and recovery expectations (Supplementary Material S1). Closed-ended responses were coded numerically and analysed using descriptive statistics, while qualitative responses were subjected to thematic content analysis to identify recurring patterns and narratives.

Ethical approval for the study was granted by the Ethics Committee of the Ministry of Environment and Sustainable Development, Guinea (approval reference: MEDD/CENAGCUE/2025/09). All participants provided informed consent prior to participation. Anonymity and confidentiality were ensured, and participation was voluntary, with the option to withdraw at any stage.

A composite resilience index was constructed at the household level to assess adaptive capacity. The index comprised three components: (i) social capital (0–1), measured through participation in family and community support networks; (ii) economic capital (0–2), based on household income sources, ownership of productive assets, access to credit, and insurance coverage; and (iii) access to essential services (0–1), including water, energy, transport, and healthcare. Each component was normalized and aggregated using equal weighting, yielding a cumulative score ranging from 0 (very low resilience) to 4 (high resilience). The index design was informed by established resilience frameworks in socio-ecological systems and adapted to the local context.

All data were anonymized prior to analysis. Statistical processing and index calculation were performed using R software (version 4.3.2).

Table 1. Distribution of respondents by category

Category of respondents	Description	Total respondents	%	Women, n	Women, %
Directly affected persons	People whose main home was totally destroyed and/or buried by the landslide	25	40.3	7	11.3
Displaced persons	People evacuated from the wider risk area (orange zone) whose homes are intact but temporarily inaccessible	25	40.3	6	9.7
Local and administrative authorities	Local elected officials, neighbourhood chiefs, representatives of deconcentrated state technical services (environment, urban planning, health)	7	11.3	2	3.2
Road construction workers	Workers employed by BGEC, Guicopres, Guiter SA on the Kagbélen-Kouria expressway project	5	8.1	0.0	0.0
Total		***62***	***100***	***15***	***24.2***

Post-disaster fieldwork

Field investigations were conducted over a seven-day period from September 20 to September 27, 2025, to assess slope instability and associated environmental disturbances. Immediate post-disaster efforts prior to this phase focused on emergency response, including medical assistance, search and recovery operations, and temporary relocation of affected populations. The field survey commenced once these critical interventions were completed.

A systematic geomorphological survey was carried out using six transects oriented perpendicular to the slope gradient. Each transect was approximately 150 m in length and spaced at 50 m intervals to ensure representative coverage of both the landslide scar and adjacent non-failed areas. Along each transect, observation points were established at regular 10–15 m intervals, resulting in a total of 20 georeferenced sampling points across the study area.

Geographic coordinates were recorded using a Garmin eTrex 32x handheld GPS device with an accuracy of ±3 m. At each observation point, georeferenced photographs and field notes were collected. Indicators of slope instability, including surface cracks (>2 cm width), visible water seepage, and slope gradients exceeding 30°, were recorded based on standardized criteria adapted from established landslide assessment frameworks.

High-resolution aerial imagery was acquired using a DJI Mavic 3E unmanned aerial vehicle equipped with a 20 MP mechanical shutter camera and RTK positioning module. Flights were conducted at altitudes ranging from 50 to 120 m, with front and side overlap of approximately 80% and 70%, respectively, yielding a ground sampling distance (GSD) of 2–5 cm. The RTK system was used to improve positional accuracy and minimize georeferencing errors.

UAV imagery was processed using Agisoft Metashape Professional (version 2.0) to generate high-resolution orthomosaics and digital surface models (DSMs). These outputs were used to delineate the landslide perimeter and quantify surface deformation. Field-based GPS measurements were used to validate and refine the photogrammetric outputs.

At each of the 20 georeferenced points, soil samples were collected from a depth of 0–50 cm using a manual hand auger. In selected locations representing distinct geomorphological units (scar, transport zone, and deposition zone), duplicate samples were collected to ensure analytical consistency. Laboratory analyses included determination of natural moisture content, bulk density, internal friction angle (φ), and effective cohesion (c'), following ASTM D3080 (direct shear test) and ASTM D4318 (Atterberg limits) standards.

Excavation volumes were estimated through a combination of field measurements and UAV-derived digital surface models, enabling cross-validation of volume calculations. Hydrological features, including drainage pathways, blocked channels, and areas of water accumulation, were mapped using GPS and documented through field observations and aerial imagery.

A triangulation approach was applied by integrating field observations (Yin, 2018), UAV-derived spatial data, and laboratory measurements to ensure consistency and robustness of the results.

Documentary and retrospective analysis

A qualitative documentary analysis combined with retrospective field validation was conducted to assess the consistency between prescribed environmental safeguards and observed field conditions. Primary sources included the Environmental and Social Impact Assessment (ESIA) and Environmental and Social Management Plan (ESMP) for the Kagbélen–Kouria expressway project (WEST Ingénierie SARL, 2022), the Environmental Compliance Certificate (ECC), as well as relevant media reports and official statements. These materials were systematically cross-referenced to identify potential gaps between planned mitigation measures and their implementation in practice, with particular attention to deviations from approved environmental procedures.

Document analysis

A structured analytical framework was developed to systematically evaluate the ESIA, ESMP, and ECC documents. The coding scheme was defined prior to analysis based on key dimensions of environmental risk and mitigation. Each document was independently reviewed by two researchers to enhance analytical reliability, with discrepancies resolved through consensus.

The analysis followed three sequential steps:

1. Risk identification: Environmental risks were extracted and classified into three categories: hydrological (e.g., drainage disruption, water source obstruction), geological (e.g., slope instability, soil erosion), and ecological (e.g., vegetation clearance, habitat fragmentation).

2. Mitigation measure assessment: For each identified risk, corresponding mitigation measures were evaluated based on three criteria: (i) specificity (degree of operational detail), (ii) feasibility (technical and logistical applicability under site conditions), and (iii) monitoring provisions (presence of defined indicators, monitoring frequency, and responsible entities).

3. Discrepancy coding: Field observations collected in September 2025 were systematically compared with prescribed measures. Discrepancies were classified according to the following operational definitions:
– Non-implementation: absence of the prescribed measure in the field;
– Partial implementation: incomplete or spatially limited application of the measure;
– Ineffective implementation: presence of the measure without achieving its intended function.

A synthesis of discrepancies between ESIA/ESMP provisions and field observations is presented in Table 2. Field observations were systematically compared with prescribed measures to evaluate their level of implementation and effectiveness. This comparative approach allowed for the identification of both partial compliance and complete non-compliance across different mitigation components. The analysis further facilitated the classification of discrepancies according to their nature and potential environmental significance. All discrepancies were recorded in a structured matrix linking prescribed measures, field observations, photographic evidence, and discrepancy categories.

Table 2. Synthesis of key discrepancies between ESIA/ESMP prescriptions and field observations

Domain	Prescribed measure (ESIA/ESMP)	Non-compliance / observed consequences
Slope/soil stabilization	Installation of anti-erosion measures (stone bunds, grass strips, tillage) and restoration of vegetation cover on slopes	Absence of erosion-control measures; evidence of extensive surface erosion and saturation-induced slope instability
Water management / drainage	Construction of drainage networks for wastewater and stormwater; installation of erosion-control traps in drainage channels	Obstructed spring outlets, presence of mudflows, and lack of effective runoff drainage infrastructure
Social compensation / resettlement	Preparation of a Resettlement Action Plan (RAP) to compensate affected populations and property owners (land, crops, dwellings) prior to construction	No evidence of compensation and absence of preventive resettlement within the right-of-way; increased social and economic vulnerability

Media content analysis

Media coverage and official communications were systematically collected from a total of 12 sources, including national newspapers (e.g., RefletGuinée, Guinee7.com, Guineenews.org), online news platforms, and official press releases issued by the Ministries of Environment and Public Works. Source selection was strictly guided by both relevance (covering articles published between 20 August and 30 September 2025) and credibility (established outlets operating under editorial oversight; see Supplementary Material Table S2 for the full list of media outlets consulted).

A structured content analysis was conducted using a predefined coding framework. Each source was coded along three analytical dimensions:
1. Causation: attribution to natural versus anthropogenic drivers;
2. Responsibility: assignment of accountability to specific actors;
3. Mitigation discourse: references to preventive or corrective actions.

Coding was performed independently by two researchers, and intercoder reliability was evaluated using Cohen's kappa ($\kappa = 0.84$), indicating strong agreement. Any discrepancies were resolved through discussion. Thematic patterns were subsequently identified to compare dominant media narratives with field-based evidence.

Qualitative data management and coding were supported using NVivo (version 14), which facilitated the systematic organization and structuring of the dataset. This systematic approach ensured methodological rigor, transparency, and reproducibility in the analysis of media coverage.

Integration and transparency

This mixed-method approach ensured reproducibility and transparency by explicitly linking analytical procedures to specific documents, coding rules, and operationalized definitions of discrepancies. Complete coding matrices and the full list of media sources are provided in the Supplementary Materials (Tables S2). All data processing workflows, including cleaning, coding, and handling of missing values, were fully documented to facilitate reproducibility.

Quantitative analysis

Quantitative data were processed and analysed using RStudio (version 2023.12.1+402) with R (version 4.3.2). Descriptive statistics, including frequencies, percentages, means, and standard deviations, summarized key variables. Associations between categorical variables (e.g., occupation and income loss) were tested using chi-square or Fisher's exact tests, depending on expected cell counts. Odds ratios with 95% confidence intervals quantified the strength of associations (e.g., likelihood of refusal to return to affected areas). Statistical significance was set at $p < 0.05$.

Data cleaning and coding adhered to established standards [cite standard references where applicable], including systematic handling of missing data. Data quality and reproducibility were ensured through version-controlled scripts and annotated workflows.

Qualitative analysis

Qualitative data, including interview transcripts and field observation notes, were analysed using thematic analysis. An initial coding framework was developed inductively from a representative subset of the data and iteratively refined through successive coding rounds. Codes were applied consistently to identify recurrent themes, contradictions, and patterns within the discourse.

Data triangulation was performed by cross-referencing field observations with interview accounts to validate interpretations. Inter-coder reliability was evaluated where appropriate, ensuring coding consistency and analytical rigor.

Spatial analysis

Spatial analyses were conducted in QGIS (version 3.28.11). Primary spatial data sources included high-resolution orthomosaics and digital surface models generated from DJI Mavic 3E drone imagery, processed using Agisoft Metashape Professional (version 2.0), complemented by field-collected GPS waypoints (Garmin eTrex 32x) at 20 observation points across the landslide zone.

Slope gradients were derived from the drone-based digital surface model and validated against field measurements obtained using a handheld clinometer at representative locations. Survey and field observation data were georeferenced and overlaid with ancillary spatial layers, including topographic maps and historical satellite imagery. Residual risk zones were delineated based on combined field and GIS-based criteria, allowing integrated visualization of environmental hazards and observed impacts. Standard GIS procedures were applied to generate slope, aspect, and elevation maps, with geospatial accuracy and error propagation documented.

Integrated analysis

This structured, multi-level analytical framework integrates quantitative, qualitative, and spatial data, ensuring transparency, reproducibility, and comprehensive assessment of the study area. Cross-validation between datasets strengthens the robustness of findings and supports evidence-based interpretation of environmental hazards.

Limitations of the study

This study presents several limitations that should be considered when interpreting the results. First, the household survey was conducted over a brief period of seven days in the immediate aftermath of the landslide, a context marked by urgency and emotional distress, which may have influenced responses. Second, although the sample captured a representative cross-section of affected households, it does not allow for statistical generalization to the entire population of Manéah, particularly marginalized or hard-to-reach groups. Third, access to administrative documents, including contracts between government authorities and construction companies, inspection reports, and correspondence, was limited, constraining the precise reconstruction of the decision-making processes related to the project's execution and oversight.

These limitations highlight the need for careful interpretation of both socio-economic and governance-related findings presented in this study.

RESULTS

The triple biophysical determination of the hazard

The Manéah landslide was fundamentally controlled by a combination of geological, pedological, and climatic conditions that set the stage for catastrophic failure. Field and laboratory analyses reveal a triple biophysical determination, where inherent slope fragility, extreme rainfall, and specific mechanical triggers converged to produce rapid slope collapse.

Geological and pedological predisposition: a fundamentally fragile system

Mount Kakoulima is part of the horst known as the "Kakoulima Islands", composed of Proterozoic–Paleozoic metamorphic and sedimentary rocks (sandstones, schists, quartzites) (Villeneuve, 2005; Augé et al., 2018). Mount Kakoulima is part of the Conakry Igneous Complex, a major mafic-ultramafic intrusive body formed during the opening of the Central Atlantic Ocean. Field lithological analyses document a stratigraphic progression from peridotite and wehrlite at depth to gabbroic rocks at higher levels, indicating complex magmatic emplacement within an older crystalline basement. This is consistent with regional geological frameworks showing that the western Guinea margin is underlain by Precambrian metamorphic and igneous rocks intruded by mafic-ultramafic bodies such as the Conakry Igneous Complex (Augé et al., 2018). The landslide mass consisted of a thick lateritic regolith, developed from prolonged chemical weathering under a hot, humid climate. This soil has two critical geotechnical properties: high water retention and effective cohesion (c') that sharply decreases upon saturation. Importantly, the ESIA for the road project explicitly identified "skeletal" and "very sensitive" soils at the slope base (WEST Ingénierie SARL, 2022), confirming pre-existing knowledge of slope vulnerability. These characteristics indicate that even moderate perturbations could destabilize the system, making the slope inherently predisposed to failure.

Climatic trigger: exceptional hydraulic overload

The landslide was initiated during an extreme rainfall event, consistent with the peak West African monsoon. Local measurements and corroborated eyewitness data indicate extraordinary precipitation in the 72 hours preceding failure. Water infiltration rapidly increased pore water pressure, reducing effective stress according to the Mohr-Coulomb failure criterion ($\tau = c' + \sigma' \tan \varphi'$). Saturation effectively transformed the lateritic regolith into a quasi-liquefied state, dramatically lowering shear strength. This demonstrates that hydraulic overloading acted as the immediate trigger, converting a predisposed slope into a dynamic failure system.

Failure mechanism: rotational-translational slide along a weakness plane

Field observations of the rupture scar (Figure 3) and debris deposits reveal a rotational-translational movement. The upper slope mass detached along a pre-existing weakness plane, likely at the interface between weathered regolith and less weathered bedrock or a plastic clay layer. Steep slopes exceeding 30° facilitated rapid downslope movement (Figure 4). The combined effect of slope geometry, soil saturation, and pre-existing structural discontinuities indicates that the failure was a deterministic outcome once hydraulic and mechanical thresholds were exceeded.

Biophysical determinants as preconditioners of anthropogenic amplification

This analysis shows that the Manéah slope possessed intrinsic instability due to geology, pedology, and climatic stress, creating a high-risk baseline. When combined with anthropogenic interventions (see Anthropogenic activation: when development becomes a risk factor section), these biophysical factors amplified the susceptibility and accelerated failure, highlighting the necessity of integrated slope management that considers both natural predispositions and human-driven triggers.

Figure 3. Rupture scar

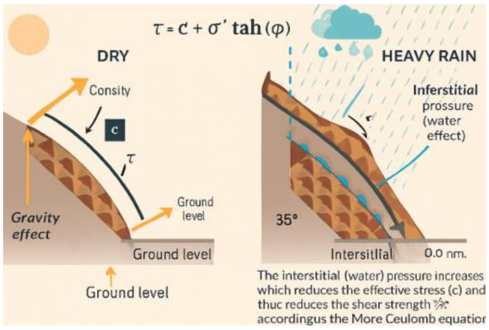

Figure 4. Mohr-Coulomb failure mechanism

Anthropogenic activation: development as a central risk factor

Human activity was the decisive factor that transformed the naturally unstable Manéah slope into a catastrophic landslide system. Field investigations and geotechnical surveys identified three primary anthropogenic mechanisms that substantially increased slope susceptibility: mechanical alteration of the terrain, hydrological mismanagement, and informal urbanization. These processes progressively modified both the structural and hydrological properties of the slope, reducing its inherent stability margin over time. In addition, the cumulative nature of these interventions suggests a gradual degradation rather than a single-point failure mechanism. These factors acted synergistically, converting a moderately hazardous slope into a high-risk system with measurable consequences for soil stability and downstream settlements.

This case provides clear evidence that unmanaged development can both trigger and amplify landslide hazards, demonstrating that anthropogenic activation is not a marginal contributor but a central determinant of slope failure. The findings underscore the urgent need for integrated engineering solutions, environmental management, and land-use governance to mitigate disaster risk in similarly exposed areas.

Direct mechanical destabilization: slope geometry alterations

The construction of the Kagbélen Kouria 2×2 expressway required deep cuts at the slope foot (Figure 5a–b), removing the natural buttress and altering stress distributions, while mid-slope excavation for a borrow pit imposed additional head loads above undermined zones. These combined interventions produced critical stress imbalances, directly triggering mass movement. Such activities reflect classical landslide initiation mechanisms (Glade & Crozier, 2005; Maki Mateso et al., 2023; Capobianco et al., 2025), but in this case were primarily anthropogenic, illustrating the scale at which infrastructure projects can destabilize slopes.

Figure 5. View of the disaster area in the municipality of Maneah (2025, august): a – landslide epicentre; b – quarry site; c – blocked spring head; d – blocked waterway

Hydrological disruption: rainfall converted into a deterministic trigger

Despite ESMP prescriptions for ditches, benches, and sediment traps, field observations revealed systematic non-implementation, resulting in uncontrolled runoff. In several locations, drainage structures were either incomplete or entirely absent, preventing adequate redirection of surface water. Construction debris blocked spring heads (Figure 5c), generating local saturation pockets that increased pore pressure within the slope. This led to spatially heterogeneous infiltration patterns, further destabilizing already weakened soil layers. Quantitative measurements indicate that soil moisture exceeded critical thresholds during rainfall events. These findings demonstrate how human mismanagement of hydrology (Figure 5d) transformed probabilistic rainfall into a deterministic landslide trigger, directly highlighting the role of governance in geohazard activation.

Informal urbanization: amplifying hazard through settlement and deforestation

The Fragafily area was progressively occupied despite known instability, driven by Conakry's land pressure and lack of enforceable urban planning (Diallo, 2015; Maki Mateso et al., 2023; Kaushal et al., 2025). Houses were constructed without geotechnical or seismic assessment, while local deforestation removed root-based reinforcement, further reducing slope cohesion. The combination of construction and vegetation loss demonstrates how informal settlements magnify existing natural risks, creating localized failure hotspots and increasing overall slope vulnerability (Figure 6).

Figure 6. Construction on unstable slopes

Social vulnerabilities and post-disaster fragmentation

The Manéah landslide produced extensive physical destruction while simultaneously exposing entrenched social inequalities and differentiated capacities for coping and recovery. Socioeconomic assessments reveal that the impacts were neither uniform nor merely spatially determined, but mediated through social structures, moral geographies, and resilience capacities.

Differentiated economic vulnerability and occupational mediation of disaster impacts

Economic vulnerability following the Manéah landslide was strongly mediated by socioeconomic position, rather than geographic exposure alone. Substantial disparities were observed across occupational groups: all farmers (100 %) reported complete losses of crops, livestock, and essential tools, while nearly 95 % of informal traders and laborers lost shops or operational equipment. In contrast, approximately 90 % of civil servants and teachers maintained regular incomes, underscoring the protective effect of formal employment structures (Pelling, 2011). A χ^2 test confirmed that occupation is a significant determinant of economic vulnerability ($p < 0.001$), highlighting the concentration of fragility within informal and manual sectors. Immediate indebtedness among households operating in the informal economy further suggests that post-disaster recovery trajectories will diverge sharply along economic and occupational lines. These findings emphasize that targeted interventions must consider both structural economic position and occupational exposure to effectively mitigate disaster impacts.

Trauma, mourning, and divergent moral geographies: risk perception and divergent recovery preferences

A pronounced social fault line emerged between directly affected individuals, whose homes were destroyed, often with missing relatives, and displaced persons, whose homes were evacuated but remained structurally intact. Quantitative analysis demonstrates stark divergences in post-disaster aspirations: 92 % of directly affected individuals categorically refused to return, describing the site as a "cemetery" and prioritizing permanent resettlement, whereas 85 % of displaced persons expressed an intent to return contingent upon the implementation of security measures, reflecting strong patrimonial attachment ("I was born here"). Fisher's exact test confirms the significance of this divergence ($p < 0.0001$; odds ratio = 241.67), indicating that directly affected households are over 240 times more likely to refuse return than displaced households.

These decisions cannot be reduced to economic rationality alone; rather, they reflect a "moral economy" of grief and collective memory, in which emotional safety, identity, and social cohesion constitute primary determinants of behaviour (Thompson, 1971). In this synthesis, these quantitative outcomes are treated as indicators shaping differentiated intervention priorities, without reiterating individual trauma narratives. Together, these findings illustrate how social position, experiential exposure, and collective memory converge to influence both recovery choices and the prioritization of post-disaster interventions.

Resilience capacities, adaptive practices, and integrated vulnerability assessment

Despite the magnitude of the Manéah landslide, immediate adaptive behaviours and mutual aid practices rapidly emerged within the affected community. Neighbours conducted initial rescue operations using rudimentary tools (shovels, picks, hoes), successfully extricating four individuals from the debris, while family and neighbourhood networks rapidly mobilized to provide emergency shelter, food, and basic sustenance.

Quantitative assessment using a resilience index (0–4 scale integrating social capital, economic capital, and access to services) revealed structured patterns of household vulnerability and adaptive capacity. The index allowed for a comparative evaluation of resilience across different household categories, highlighting systematic disparities in recovery potential. The overall mean score was 1.9, with directly affected households averaging 1.7 and displaced households 2.1, indicating that complete loss of property and social infrastructure substantially suppresses immediate resilience (Figure 7). This difference suggests that displacement, while disruptive, may in some cases be associated with access to alternative support networks or temporary resources. The survey population comprised 66 % men (41/62), 24 % women (15/62), and 10 % youth (6/62), reflecting prevailing household headship norms and differential availability for interviews (Table 3). These demographic patterns also influence the representation of perspectives captured in the dataset. Occupational distribution (Table 3) highlights that informal sector participants and manual laborers, 45 % traders (28/62) and 24 % workers (15/62), experienced the greatest exposure, underscoring the structural influence of socioeconomic position on disaster vulnerability. This distribution further indicates that livelihoods dependent on daily income are particularly sensitive to disruption from hazard events.

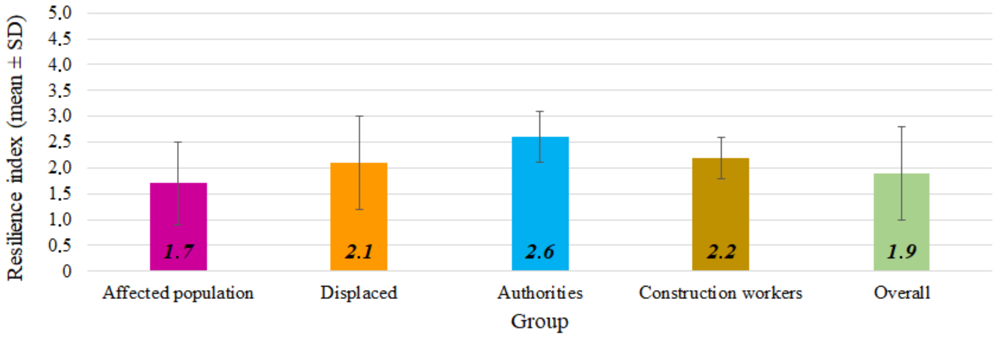

Figure 7. Socio-demographic profile of respondents

Table 3. Participant characteristics, disaster impacts, and resilience indices

Variable	Category	Sample size, n	Frequency, %
Sex	Male	41	66.1
	Female	15	24.2
	Youth (<18 years)	6	9.7
Age group	20–35 years	43	69.4
	36–55 years	17	27.4
	≥56 years	2	3.2
Socio-professional category	Merchant	28	45.2
	Worker	15	24.2
	Farmer	12	19.4
	Civil servant / Executive	7	11.3
Education level	Primary	16	25.8
	Secondary	37	59.7
	University	2	3.2
	None	7	11.3
Income loss	Yes	55	88.7
	No	7	11.3
Housing destroyed	Yes	25	40.3
	No	37	59.7
Refusal to return (affected population)	Yes (refusal)	23	92.0
	No (willing to return)	2	8.0
Willingness to return (displaced population)	Yes (willing)	21	84.0
	No (refusal)	4	16.0

Resilience assessment further informed an integrated vulnerability framework. Sixty-three percent of households scored low (1–2), indicating urgent support needs, with directly affected households exhibiting lower resilience relative to displaced households (Figure 8). By combining economic loss and resilience scores, households were classified into three vulnerability tiers: high vulnerability (complete income loss and low resilience, predominantly directly affected traders and workers), moderate vulnerability (partial income loss and moderate resilience, primarily some displaced households), and low vulnerability (minor income loss and high resilience, mostly formal sector households). This classification provides a structured basis for prioritizing interventions according to both material loss and adaptive capacity, as illustrated in Figure 9.

Together, these findings demonstrate that community resilience and recovery potential are mediated by both socioeconomic position and disaster exposure. Integrating demographic, occupational, economic, and resilience indicators allows evidence-based targeting of interventions, ensuring support is directed toward households with the greatest need while accounting for their capacity to adapt and recover.

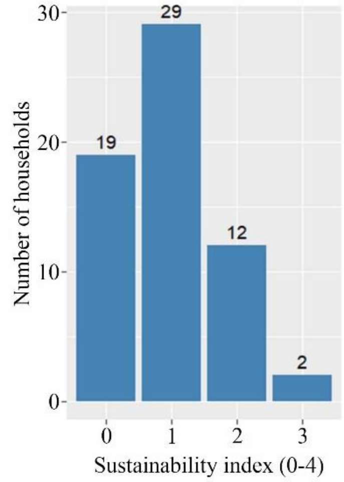

Figure 8. Distribution of the community resilience index

Figure 9. Distribution of household vulnerability by group (directly affected vs. displaced) combining economic loss and resilience index

Social vulnerability as a multilayered amplifier of disaster impact

The Manéah landslide thus compounded physical hazards with profound social inequalities, generating distinct trajectories of risk perception, recovery potential, and moral interpretation. These findings underscore the multilayered nature of vulnerability, encompassing economic, emotional, and social dimensions, and highlight that effective disaster mitigation strategies require interventions addressing both material reconstruction and social cohesion.

Systemic failure of environmental governance

The Manéah landslide exposes not only physical and social vulnerabilities but also a systemic failure of environmental governance, in which institutional gaps directly amplified hazard impacts. Evidence from documentary sources, field observation, and interviews with administrative officials indicates cascading governance failures, resulting in a landscape characterized by regulatory impotence and fragmented accountability.

ESIA and ESMP: formal compliance without operational substance

The existence of a "Category 1" Environmental and Social Impact Assessment (ESIA) and a detailed Environmental and Social Management Plan (ESMP) confirms that environmental risks were formally recognized and anticipated. Nevertheless, field investigations reveal complete non-implementation of prescribed mitigation measures. Drainage structures, erosion-control benches, and sediment traps were either absent or rendered dysfunctional. The Environmental Compliance Certificate (ECC) issued to Guiter SA functioned primarily as an administrative ritual, disconnected from meaningful operational oversight. These findings illustrate that formal environmental assessments, when decoupled from enforcement mechanisms, fail to translate into hazard prevention, effectively rendering the regulatory framework inert.

Fragmented responsibilities and operational non-accountability

The road project involved three contractors, BGEC, Guicopres, and Guiter SA, whose coordination was severely deficient, resulting in spatially heterogeneous implementation and localized zones of environmental neglect. Only Guicopres, acting independently, executed slope stabilization measures within its assigned section. The diffusion of responsibilities produced institutional gaps in which no single actor could be held accountable for environmental management, exacerbating systemic vulnerability. This fragmentation underscores the critical importance of integrated oversight in complex infrastructure projects.

Absence of preventive urban planning: unchecked exposure

Despite the well-documented susceptibility of the Manéah area, no risk zoning or land-use planning had been enforced. Urban expansion proceeded in an unregulated manner, with informal settlements occupying highly unstable slopes. The absence of anticipatory spatial governance ensured that the human-environment system remained highly exposed to predictable hazards, transforming a geophysical risk into a social catastrophe.

Governance deficits as a multiplier of disaster risk

Collectively, these failures illustrate a systemic deficit in environmental governance. The combination of ritualized ESIA processes, fragmented contractor responsibilities, and absent preventive planning amplified the consequences of natural and anthropogenic triggers. The Manéah disaster demonstrates that institutional design, enforcement, and coordination are as critical to slope stability as geotechnical and hydrometeorological factors, positioning governance as an essential layer in landslide risk management.

Implications for recovery interventions

The combined statistical insights underscore the need for differentiated, evidence-based recovery strategies:
– Targeted economic assistance for traders, workers, and farmers experiencing near-total income loss;
– Dual resettlement options accommodating the divergent aspirations of directly affected versus displaced households;
– Resilience-oriented support tailored to household vulnerability tier, including access to social networks, services, and livelihood restoration.

By integrating demographic, occupational, economic, and resilience indicators, this analysis preserves the original findings while offering a structured lens for prioritizing interventions. The observed differences are statistically significant, socially meaningful, and operationally actionable for post-disaster recovery planning.

DISCUSSION

Urbanization and social vulnerability in hazard-prone contexts

The Manéah landslide exemplifies a pattern increasingly documented across African cities: rapid, unplanned urban expansion disproportionately exposes the most vulnerable populations to hazard-prone areas, including unstable slopes, floodplains, and industrial perimeters (Fekete et al., 2023;

journal homepage: https://www.teiee.net/

Andreasen et al., 2023). Populations occupying such zones do so primarily due to constrained land options, themselves shaped by political and economic structures that render them effectively invisible until disaster strikes. In contrast, civil servants' relative resilience demonstrates that formal employment and state affiliation act as a protective buffer against shocks, revealing how disasters expose entrenched social inequalities (Middelanis et al., 2025; Madubula & van Eeden, 2024).

Comparative insights from African urban settings

Evidence from other African contexts reinforces these patterns. In Nairobi, April 2024 floods highlighted severe discrepancies between top-down assessments and community realities: Pamoja Trust reported approximately 1,417 residents within a 60-meter riparian buffer, while official satellite-based assessments captured only 118 (Olando & Dick, 2026). This mismatch illustrates the limitations of purely technical, centralized disaster assessments. Similarly, in Kananga, DRC, over 60 erosion gullies intersect the urban area, contributing to the collapse of more than 500 buildings and affecting 17,000 people (Global Centre on Adaptation, 2025). The interaction of naturally erodible soils, inadequate drainage, and unregulated construction transformed latent geophysical hazards into urban catastrophes. There, integrated urban resilience interventions combining nature-based stabilization, drainage improvements, and local capacity building demonstrated that technical solutions require embedding within robust institutional and social frameworks.

In Sarh, Chad, recurrent floods linked to the Chari River prompted the establishment of multisectoral disaster committees (MCR2030, UNDRR, 2025). As in Manéah, fragmented institutional mandates and coordination gaps were the primary challenges, underscoring that governance deficits can be as decisive as physical exposure in determining disaster outcomes.

Governance, regulatory gaps, and risk creation

A central insight from Manéah is the disconnect between formal regulatory frameworks and on-the-ground implementation. Despite the presence of an Environmental Code, ESIA procedures, and Environmental Compliance Certificates, non-compliance and absent enforcement reduced formal obligations to ritualized exercises. This observation aligns with the "checkbox exercise" (Cashmore, 2004; Nadeem & Fischer, 2011) and the "normalization of deviance" (Vaughan, 1996), demonstrating that repeated non-enforcement renders known hazards socially acceptable until catastrophe occurs.

Social differentiation in recovery and moral economy

The observed divergence between directly affected and displaced populations in recovery preferences underscores critical issues of environmental justice, land rights, and the moral economy of risk. Post-flood resettlement in Nairobi involved coercive evictions without consultation or compensation (Olando & Dick, 2026), whereas in Kananga participatory approaches integrated stabilization, drainage, and community co-design (Global Centre on Adaptation, 2025). These contrasts demonstrate that resettlement outcomes are not inevitable consequences of hazard exposure, but contingent upon governance strategy, institutional capacity, and community engagement.

Early warning systems and community-based risk communication

Early warning systems emerge as a cross-cutting lesson. Evidence from Niger indicates that locally calibrated, easily interpretable systems outperform complex predictive models in promoting timely action (Tarchiani et al., 2021). In Manéah, 97 % of respondents reported not perceiving warning signs, highlighting the urgent need for community-based, actionable early warning frameworks.

Contributions to urban hazard research in Africa

This study advances the literature on urban hazards in African cities in several ways:

– Contextual extension: It documents a landslide in a West African urban environment, integrating biophysical and socioeconomic analyses, and expands the research focus beyond the more frequently studied floods.
– Governance-cantered risk creation: It demonstrates that political and institutional decisions, or their absence, can transform natural hazards into disasters.
– Differentiated vulnerability analysis: It provides statistically robust evidence of fractures between directly affected and displaced households, emphasizing the need for tailored recovery interventions.
– Comparative perspective: By situating Manéah alongside other African cities, it identifies recurrent structural trends, including informal urbanization, institutional fragmentation, and the gap between formal regulations and practical enforcement.
– Conceptual advancement: It proposes a systemic risk model (Table 4) synthesizing the interplay of biophysical predispositions, human-induced stressors, governance failures, and social vulnerabilities, offering a framework for both local interventions and broader urban risk management strategies.

Despite the comprehensive insights gained from the Manéah case, several critical gaps remain in understanding and addressing urban landslide risk. The trajectories of resilience among directly affected and displaced households are still poorly documented over the medium term, limiting knowledge of factors that promote or hinder recovery. Comparative analyses of environmental governance frameworks across major infrastructure projects in Guinea, including roads, mines, and dams, are largely absent, leaving systemic determinants of governance failure insufficiently understood. Furthermore, methods for participatory risk mapping and inclusive urban planning have yet to be fully tested or integrated, highlighting an ongoing need to examine how local communities can be more effectively involved in generating actionable knowledge about their environments. These observations indicate that, while technical and biophysical mechanisms are increasingly mapped, the interplay of governance, social dynamics, and community agency remains an unresolved dimension of urban disaster risk in West Africa. Ultimately, the Manéah landslide reinforces that disasters in the region are not solely triggered by natural hazards, but by governance failures that leave the most vulnerable populations exposed, underlining the ethical and political imperatives of risk-informed urban development.

CONCLUSION

The Manéah landslide demonstrates that urban disasters in the Guinean Anthropocene are predominantly the product of systemic governance failures rather than solely natural triggers. The study confirms that the accumulation of anthropogenic modifications, including unregulated slope cuts, infrastructure projects executed without enforceable ESMP compliance, and uncontrolled informal settlement expansion, significantly amplified exposure to rainfall-induced landslides. Vulnerability was found to be structurally differentiated: households in the informal sector, particularly those experiencing complete property loss, endured substantially greater economic and social disruption than formally employed state-affiliated households. Quantitative analysis revealed that directly affected households scored on average 1.7 on the 0–4 resilience index, whereas displaced households scored 2.1, and Fisher's exact test indicated that directly affected households were over 240 times more likely to refuse return ($OR = 241.67$, $p < 0.0001$). These findings empirically confirm the protective role of formal employment and institutional affiliation against hazard impacts.

Table 4. Integrated conceptual model of landslide risk production in Manéah (author's design)

Phase	Phase name	Constitutive elements	Description and role in the process
0	Historical and political context	– Priority given to rapid infrastructure development – Weak environmental governance – Urban land pressure	Establishes the broader socio-political and historical environment conducive to risk accumulation. Sets the rules of the game or their absence
1	Accumulation of vulnerabilities	– Biophysical predisposition: lateritic soils, steep slopes – Aggravating anthropogenic factors: deforestation, informal urbanization – Governance failures: non-application of norms, absence of planning	Long-term phase in which preconditions for disaster are created. Each element increases systemic fragility
2	Catalysing event	– Kagbélen Kouria road project – Mechanical actions (slope cuts, borrow pits) – Hydrological disruption (drainage failure) – Diffusion of responsibilities among contractors	A large-scale intervention that triggers pre-existing vulnerabilities, altering the physical and hydrological balance of the slope
3	Immediate trigger	Heavy rainfall (hydraulic overload)	Climatic event providing the final energy (soil saturation) to initiate slope failure. Acts as the "straw that breaks the camel's back"
4	System rupture	Catastrophic landslide (August 20, 2025)	Materialization of accumulated risk through the cascading interaction of biophysical, anthropogenic, and governance factors Tangible and dramatic outcome of the disaster
5	Differentiated impacts and feedback loops	Direct impacts: – Trauma and grief – Economic impoverishment – Social polarization (directly affected vs displaced) Potential feedback loops: – Reinforcement of refusal to return – Exacerbation of future social vulnerability – Increased poverty – future economic vulnerability – Possible stimulus for institutional reforms	Consequences of the disaster, illustrating how impacts can either worsen future vulnerabilities (vicious cycles) or, in optimal scenarios, lead to transformative resilience. Empirical linkage to Figures 8 and 9 demonstrates the distribution of resilience and economic loss across households, supporting targeted intervention strategies

This research achieves its objectives by statistically validating the divergence between directly affected and displaced populations and linking these outcomes to governance shortcomings. The study provides a novel empirical integration of biophysical, infrastructural, governance, and social vulnerability dimensions in a West African urban landslide context—a perspective previously absent in the literature. Unlike prior studies that examine either hazard modelling or social vulnerability in isolation, this work demonstrates how cumulative decisions, institutional fragmentation, and insufficient regulatory enforcement convert latent geophysical hazards into urban disasters.

By explicitly documenting the interaction between environmental governance failures and rapid urbanization, the study addresses a critical knowledge gap, illustrating how such failures generate differentiated risk profiles and socially mediated outcomes. The combined use of field surveys, UAV mapping, ESIA compliance assessment, and statistical analysis establishes a replicable methodological framework for evaluating urban landslide risk in complex socio-environmental settings. Consequently, the findings advance understanding of risk production mechanisms, provide a robust empirical basis for assessing social dimensions of vulnerability, and contribute to the emerging discourse on transformative urban resilience in sub-Saharan African cities.

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Author's statements

Contributions

Not applicable.

Declaration of conflicting interest

The author declares no conflicts of interest.

Financial interests

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to privacy and ethical restrictions, survey data containing personal information are not publicly available.

AI disclosure

The author declares that generative artificial intelligence was not used to assist in writing or revising this manuscript. All content was developed through the author's own analysis, synthesis, and writing.

Ethical approval declarations

This study adhered to ethical guidelines for research involving human participants. The research protocol was reviewed and approved by the Institutional Research Committee of the Ministry of Environment and Sustainable Development, Guinea (approval reference: MEDD/CENAGCUE/2025/09). Informed consent was obtained in writing from all individuals who participated in the study. Participants were informed of their right to withdraw at any time, and all data were anonymized to ensure confidentiality.

Additional information

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