

Assessment of Flood Risks on Power Infrastructure and Renewable Energy Installations in Ogba-Egbema-Ndoni Local Government Area, Rivers State

¹David, P. A., ¹Iyama, W. A & ¹Gobo, A. E

¹Institute of Geosciences and Environmental Management, Rivers State University Nkpolu-Oroworukwo
Port Harcourt, Rivers State, Nigeria

Corresponding Email: david.precious@rsu.edu.ng

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Abstract

This research evaluated the flood hazards that impact power systems and renewable energy setups in the Ogba-Egbema-Ndoni Local Government Area (ONELGA) located in Rivers State, Nigeria. The primary goals included investigating how vulnerable energy infrastructure is to factors such as flood depth, speed, and duration; studying the vital interconnections between energy networks and other crucial services including water provision, healthcare, and transport; and calculating the economic damage and downtime caused by flood effects. A descriptive cross-sectional survey design was used alongside case studies and analytical methods. Information was gathered through structured questionnaires, interviews, and firsthand observations from a sample of 378 individuals chosen through stratified random sampling from key communities in ONELGA. Additionally, secondary information from credible institutional and academic resources was incorporated. The quantitative data analysis utilized descriptive statistics, while qualitative information was reviewed thematically. Geographic Information Systems (GIS) techniques were also employed to evaluate the spatial patterns of flood vulnerability. Results indicated that energy infrastructure within ONELGA is extremely susceptible to flooding, with 92% of participants reporting power outages during significant flood events. The infrastructure that was most impacted included transformers and substations, followed by electricity poles and renewable energy setups. Flood-related power interruptions greatly disrupted vital services, such as water supply (62.4%), communication (56.1%), health services (48.7%), and transportation (44.4%). The research also demonstrated strong connections between energy networks and socio-economic activities, with nearly half of the participants noting income reductions due to power outages and more than 50% suffering damage to their electrical devices. The average financial loss was calculated at ₦92,500, primarily affecting traders and fishermen. The downtime for infrastructure varied from one to eight weeks, suggesting extended recovery delays. The study concludes that energy infrastructure in ONELGA faces significant flooding risks, leading to considerable economic and social implications. It advocates for more resilient infrastructure designs, improved early warning mechanisms, and enhanced coordination among institutions to minimize vulnerability.

Keywords: Flood risk, energy infrastructure, renewable energy, interdependency, economic & loss

Introduction

Flooding has emerged as one of the most devastating environmental hazards in Nigeria, particularly in the Niger Delta region, where Rivers State is located. The low-lying terrain, coupled with heavy rainfall and poor drainage systems, makes communities highly vulnerable to recurrent flood events. Floods not only displace populations but also damage critical infrastructure, disrupt livelihoods, and pose long-term risks to sustainable development (Abu-hanifa et al., 2025). In Ogba-Egbema-Ndoni Local Government Area (ONELGA), the situation is compounded by the presence of extensive energy infrastructure, including conventional power installations and emerging renewable energy projects, which are increasingly exposed to flood hazards.

The vulnerability of power infrastructure to flooding is a pressing concern because electricity supply is central to economic growth, healthcare delivery, and industrial productivity. Floodwaters can damage substations, transmission lines, and distribution networks, leading to prolonged outages and costly repairs. In Rivers State, recent flood disasters have caused widespread destruction of homes, farmlands, and public utilities, leaving thousands displaced and critical facilities incapacitated (International Organisation for Migration [IOM], 2024). Such disruptions highlight the fragility of energy systems in flood-prone regions and underscore the need for comprehensive risk assessments. Renewable energy installations, such as solar farms and small-scale hydro projects, are often promoted as resilient alternatives to conventional power systems. However, they are not immune to flood risks. Solar panels, inverters, and battery storage units can be damaged by inundation, while hydro facilities may face structural challenges during extreme flood events. The increasing push for renewable energy in Nigeria, aligned with global climate change mitigation goals, requires careful consideration of local environmental hazards. Without adequate flood risk management, investments in renewable energy could suffer setbacks, undermining both energy security and climate adaptation strategies (Ijeomanta, 2023).

Flood disasters in Rivers State have been linked to a combination of natural and anthropogenic factors, including intense rainfall, river overflow, poor urban planning, and inadequate drainage infrastructure. The impacts are often severe, with reports of over 628,000 people affected and more than 160,000 displaced during the 2024 flood season alone (IOM, 2024). These figures illustrate the scale of vulnerability and the urgent need for localised studies that assess how specific sectors, such as energy, are impacted. ONELGA, with its strategic role in Nigeria's energy landscape, presents a critical case study for understanding the intersection of flood risks and energy infrastructure resilience.

Aim & Objectives

The aim of this study is to assess the flood risks affecting power infrastructure and renewable energy installations in Ogba-Egbema-Ndoni Local Government Area, Rivers State. To achieve this aim, the study pursued the following objectives to:

- i. Assess the susceptibility of power infrastructure and renewable energy installations to flood depth, velocity, and duration.
- ii. Examine critical interdependencies between power infrastructure, renewable energy installations, and other systems such as water supply, health facilities, and transportation during flood events.
- iii. Estimate potential economic losses and downtime resulting from flood damage to power and renewable energy infrastructure in ONELGA.

Research Questions

Based on the aim and objectives of this study, the following research questions are formulated to guide the investigation:

- i. How vulnerable are power infrastructure and renewable energy installations to flood depth, velocity, and duration in ONELGA, Rivers State?
- ii. What are the critical interdependencies between power infrastructure, renewable energy installations, and other systems such as water supply, health facilities, and transportation during flood events in ONELGA?
- iii. What are the potential economic losses and downtime resulting from flood damage to power and renewable energy infrastructure in ONELGA?

Methodology

This study employed a descriptive cross-sectional survey design complemented with case study and analytical components to examine the impact of recurrent flooding on energy infrastructure in Ogba–Egbema–Ndoni Local Government Area (ONELGA), Niger Delta, Nigeria. The descriptive cross-sectional approach facilitated the systematic collection and analysis of data at a single point in time, enabling an accurate representation of prevailing conditions related to flooding, infrastructure vulnerability, and community responses.

The survey component was particularly appropriate given the study's objective of gathering data from a broad population comprising community residents, energy facility managers, and local government officials. Data were collected through structured questionnaires and interviews, allowing for the integration of both quantitative indicators—such as flood frequency and infrastructure damage—and qualitative insights, including stakeholder perceptions and coping strategies. This mixed evidence base provided a comprehensive understanding of the phenomenon under investigation. In addition, a case study approach was adopted, with ONELGA serving as a representative flood-prone area within the Niger Delta. This approach enabled an in-depth exploration of the complex interactions between environmental conditions, socio-economic activities, and energy infrastructure systems. Although context-specific, the findings offer insights that may be cautiously generalized to similar flood-prone regions.

To strengthen analytical rigor, the study incorporated statistical modelling techniques, including descriptive statistics and population projection using the exponential growth model. These analytical tools facilitated the identification of patterns and relationships between flooding events and energy infrastructure resilience. The study utilized both primary and secondary data sources to ensure methodological robustness and comprehensive coverage of the research problem. Primary data were obtained through field-based methods, including structured questionnaires, semi-structured interviews, and direct observations. Questionnaires were administered to residents across selected communities in ONELGA to capture experiences related to flooding, impacts on energy systems, and adaptive strategies. Interviews conducted with key stakeholders—such as energy facility managers, community leaders, and government officials—provided in-depth qualitative insights into operational challenges and mitigation efforts. Observational data further complemented these methods by providing firsthand evidence of infrastructure conditions and flood-prone locations. Secondary data were sourced from relevant published and unpublished materials, including government reports, hydrological and meteorological datasets, census records, and scholarly literature. Rainfall and flood data were obtained from national agencies, while demographic information was derived from official population statistics. These sources provided

contextual and empirical support for the analysis of flood risks and infrastructure vulnerability (Nweke. & Amachere, 2026). The study population comprised residents of ONELGA alongside key stakeholders involved in energy infrastructure management and governance. Due to the large population size, a representative sample was selected to ensure reliability and generalizability of findings. A stratified random sampling technique was employed to capture diverse perspectives across the study area. ONELGA was stratified into major communities, including Omoku, Ndoni, Egbema, Obrikom, and Ebocha. Respondents were randomly selected within each stratum, ensuring proportional representation of both urban and rural populations as well as stakeholders directly involved in energy systems.

The sample size was determined using Yamane's (1967) formula, expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

where n represents the sample size, N the population size, and e the level of precision. Using a projected population of 514,000 and a 5% margin of error, a sample size of 400 respondents was obtained. This sample was proportionally distributed across the identified strata to ensure balanced representation. A mixed-methods approach was adopted, combining quantitative and qualitative techniques to provide a holistic understanding of the research problem. Quantitative data were collected through structured questionnaires designed to capture information on flood frequency, severity, infrastructure damage, and household coping mechanisms. Qualitative data were obtained through semi-structured interviews with key stakeholders, allowing for deeper exploration of operational challenges, policy gaps, and resilience strategies. Direct observation was also employed to assess physical conditions of energy installations and flood-prone areas, thereby enhancing data validity through triangulation. Secondary data collection involved the review of relevant documents, including hydrological records, policy reports, and academic publications. The integration of these methods ensured that both empirical measurements and contextual insights were captured, thereby improving the reliability and depth of the findings. Data analysis was conducted using both quantitative and qualitative techniques. Quantitative data from questionnaires were coded and analysed using statistical software. Descriptive statistics—including frequencies, percentages, and mean values—were used to summarise data and identify patterns related to flooding and infrastructure vulnerability. Inferential statistical techniques were also applied where necessary. Analysis of variance (ANOVA) was used to examine relationships between demographic variables and perceptions of flood risks, while correlation analysis was employed to assess the association between flood frequency and infrastructure damage (Wadi, et al ,2026). These analyses provided empirical evidence to support the study's conclusions. Qualitative data from interviews and observations were analysed using thematic analysis. Responses were transcribed and categorized into recurring themes reflecting stakeholder experiences, challenges, and adaptive strategies. This approach enabled a deeper understanding of contextual issues that could not be captured through quantitative methods alone. To complement survey and interview data, Geographic Information Systems (GIS) and remote sensing techniques were employed to analyse flood risk and spatial vulnerability patterns in ONELGA. The GIS analysis followed standard procedures for flood susceptibility mapping and spatial risk assessment. Spatial datasets included Digital Elevation Models (DEM), drainage networks, rainfall data, land use/land cover information, and energy infrastructure locations. These datasets were processed to derive key parameters such as elevation, slope, drainage density, and flood-prone zones. The analysis involved delineation of the study area, extraction of elevation data, and identification of

low-lying regions susceptible to flooding. Additional layers, including land use and infrastructure distribution, were integrated to assess the spatial relationship between flood risk and energy systems. This geospatial approach provided visual and analytical insights into the distribution of flood hazards and their implications for energy infrastructure resilience, thereby enhancing the overall robustness of the study (Nweke et al. 2018).

Results

Table 1: Demographic Characteristics of Respondents

Group	Frequency	Percentage (%)
Sex		
Male	202	53.4
Female	176	46.6
Age Group		
18–30 years	98	25.9
31–45 years	126	33.3
46–60 years	104	27.5
60+ years	50	13.2
Level of Education		
No formal education	34	9.0
Primary school	62	16.4
Secondary school	178	47.1
Tertiary	104	27.5
Occupation		
Farming	86	22.8
Fishing	68	18.0
Trading	72	19.0
Civil servant	42	11.1
Artisan	54	14.3
Other	56	14.8
Duration		

Less than 5 years	42	11.1
5–10 years	86	22.8
11–20 years	112	29.6
More than 20 years	138	36.5

The data illustrated in Table 1 indicates that the demographic distribution of participants is relatively even between genders, with males representing 53.4% and females comprising 46.6%, suggesting an equitable representation of both sexes in this research. Concerning age demographics, the largest segment of respondents belongs to the economically active age bracket of 31–45 years (33.3%), followed by those aged 46–60 years (27.5%) and 18–30 years (25.9%), while only 13.2% are over 60 years old. This implies that the results primarily capture the experiences of individuals who are actively engaged in economic activities, thereby making them more susceptible to the effects of flooding on energy systems. As for educational qualifications, a significant portion of respondents has at least completed secondary education (47.1%), with those holding tertiary education at 27.5%, reflecting a population that is relatively literate and capable of grasping environmental and infrastructural issues. In terms of occupations, respondents are involved in various sectors, including farming (22.8%), trading (19.0%), fishing (18.0%), artisanal work (14.3%), civil service (11.1%), and other jobs (14.8%), showing a diverse economic landscape that strongly relies on energy accessibility. Furthermore, a considerable number of respondents (36.5%) have resided in the region for over 20 years, suggesting a deep understanding of flood patterns and the performance of infrastructure over time. This demographic overview suggests that the respondents have sufficient experience, exposure, and socio-economic involvement to offer reliable insights into the vulnerability of energy infrastructure to flooding. The prevalence of economically active individuals and long-term residents enhances the reliability of the subsequent results regarding infrastructure susceptibility.

Research Objective One: To Assess the susceptibility of power infrastructure and renewable energy installations to flood depth, velocity, and duration.

Table 2: Energy Infrastructure Susceptibility and Flood Impact in ONELGA

Variable / Indicator	Category / Response	Frequency (n=378)	Percentage (%)
Main Source of Electricity	Gas Plant (Direct Loop)	208	55.0
	Generator	113	30.0
	National Grid (PHED)	45	12.0
	Solar Panel	12	3.0
	Total	378	100
Loss of Electricity During Last Major Flood	Yes	348	92.0
	No	19	5.0
	Not Applicable	11	3.0
	Total	378	100
Impact of Power Loss on Essential Services*	Water Supply	236	62.4
	Disrupted		

Physical Damage to Electricity Facilities*	Communication Disrupted	212	56.1
	Health Services Affected	184	48.7
	Transportation Disrupted	168	44.4
	No Impact	24	6.3
	Transformer/Substation Damage	—	82.0
	Fallen Electricity Poles	—	68.0
	Flooded	—	45.0
	Inverter/Battery Room		
	Damaged Solar Panels	—	28.0
	Other Structural Issues	—	15.0
Inability to Access Healthcare, Water, or Markets	No Visible Damage	—	3.0
	Yes	257	68.0
	No	110	29.0
	Not Applicable	11	3.0
Total		378	100

The results presented in Table 2 indicates that the leading source of electricity for the majority of households is gas plant direct-loop supply (55.0%), with generators accounting for 30.0%, while the dependence on the national grid (12.0%) and solar energy (3.0%) remains minimal. This highlights a significant reliance on localized and self-sustained energy sources, which are typically prone to environmental disturbances. A noteworthy observation is that 92.0% of respondents experienced electricity outages during the most recent significant flood, revealing a considerable vulnerability of both traditional and alternative energy systems to flooding events. The repercussions of power outages have a profound effect on vital services, with water supply being the most severely impacted (62.4%), followed by communication (56.1%), health services (48.7%), and transportation (44.4%). A mere 6.3% reported no effects, illustrating the extensive disruptions caused by flooding. In terms of physical destruction, transformers and substations faced the most damage (82.0%), with fallen electricity poles (68.0%) and inundated inverter/battery systems (45.0%) also being affected, and damage to solar installations (28.0%) further indicates that renewable energy setups are not protected from flood threats. Additionally, 68.0% of participants noted they could not access healthcare, water, or markets due to downed power infrastructure, underscoring the ripple effects of infrastructure collapse. The results clearly indicate that energy infrastructure in ONELGA is particularly susceptible to flood depth, duration, and related impacts, resulting in widespread service interruptions and infrastructural damage. Both conventional and renewable energy systems are notably impacted, affirming the energy sector's vulnerability to flooding.

Research Objective Two: To examine critical interdependencies between power infrastructure, renewable energy installations, and other systems such as water supply, health facilities, and transportation during flood events.

Table 3: Critical interdependencies between power infrastructure, renewable energy Installations, and other systems such as water supply, health facilities, and transportation During Flood Events.

Variable / Indicator	Category / Response	Frequency	Percentage (%)
Household Expenditure on Alternative Energy	Nothing	28	7.4
	Under ₦5,000	54	14.3
	₦5,000 – ₦20,000	120	31.7
	₦20,001 – ₦50,000	94	24.9
	Above ₦50,000	82	21.7
	Total	378	100
Loss of Electrical Appliances Due to Floodwater	Yes	198	52.4
	No	180	47.6
	Total	378	100
Cost of Repairing/Replacing Damaged Appliances*	Under ₦10,000	28	14.1
	₦10,000 – ₦50,000	54	27.3
	₦50,001 – ₦100,000	62	31.3
	Above ₦100,000	54	27.3
	Total (n = 198)	198	100
Business/Income Loss Due to Power Outage	Yes	188	49.7
	No	118	31.2
	Not Applicable	72	19.0
	Total	378	100

The results presented in Table 3 reveals that power outages caused by flooding create considerable economic and functional challenges for families. A significant number of respondents reported incurring costs for alternative energy sources, with 31.7% spending between ₦5,000 and ₦20,000, while 21.7% spent over ₦50,000, demonstrating a notable financial burden during these outages. Additionally, 52.4% of the participants indicated they lost electrical equipment due to water damage from floods, which signifies direct financial losses associated with infrastructure failures. Among those impacted, a large segment faced high costs for repairs or replacements, as 31.3% spent between ₦50,001 and ₦100,000 and 27.3% exceeding ₦100,000, which further highlights the serious economic strain faced.

In addition, almost fifty percent of those surveyed (49.7%) reported suffering business or income reductions due to outages, showing how interruptions in electrical supply directly influence livelihoods and economic activities. The results underscore significant interdependencies between energy infrastructure and other socio-economic systems, especially regarding household well-being, business functioning, and service provision. Power interruptions during floods have cascading repercussions that go beyond the energy sector, impacting income, asset safety, and overall economic stability.

Research Objective Three: To Estimate potential economic losses and downtime resulting from flood damage to power and renewable energy infrastructure in ONELGA.

Table 4: Estimate potential economic losses and downtime resulting from flood damage to power and renewable energy infrastructure in ONELGA.

Variable / Indicator		Category / Response	Frequency	Percentage (%) / Details
Estimated Income Loss (General)		Average Loss	—	₦92,500
		Range	—	₦25,000 – ₦350,000
Estimated Income Loss by Occupation		Farming	—	₦30,000–150,000 (Avg: ₦85,000)
		Fishing	—	₦40,000–200,000 (Avg: ₦110,000)
		Trading	—	₦25,000–350,000 (Avg: ₦140,000)
		Artisan	—	₦30,000–150,000 (Avg: ₦80,000)
		Civil Servant	—	₦25,000–80,000 (Avg: ₦50,000)
Downtime for Energy Infrastructure Restoration		Substations	—	2–6 weeks
		Transmission Lines	—	1–4 weeks
		Distribution Transformers	—	1–3 weeks
		Solar Installations	—	1–4 weeks
		Gas Plant Equipment	—	2–8 weeks
Perceived Responsibility for Protecting Infrastructure		PHED	218	57.7
		LGA Government	56	14.8
		State Government	42	11.1
		Community Members	28	7.4
		NEMA/SEMA	18	4.8
		Others (Gas Plant Operators)	16	4.2

Variable / Indicator	Category / Response	Frequency	Percentage Details (%)
	Total	378	100
Community Actions Taken	Raised Transformer Platforms	72	19.0
	Dug Drainage Channels	54	14.3
	Relocated Poles	28	7.4
	Awareness Meetings	42	11.1
	No Action Taken	168	44.4
	Other Actions	14	3.7
	Total	378	100
Support for Relocation of Infrastructure	Yes	268	70.9
	No	44	11.6
	Not Sure	66	17.5
	Total	378	100
	Total	378	100
Rating of LGA Preparedness	Very Poor	168	44.4
	Poor	94	24.9
	Moderate	62	16.4
	Good	34	9.0
	Excellent	20	5.3
	Total	378	100
Support for Early Warning System	Yes	342	90.5
	No	36	9.5
	Total	378	100

The findings in Table 4 demonstrate that flood-related interruptions lead to notable economic losses among various occupational categories. The average estimated income loss is approximately ₦92,500, with a broad range from ₦25,000 to ₦350,000, reflecting differing levels of vulnerability tied to economic activity. Traders experienced the highest average losses (₦140,000), closely followed by the fishing sector (₦110,000), agriculture (₦85,000), craftsmen (₦80,000), and public employees (₦50,000), highlighting that informal sectors and those reliant on energy are impacted the most. Regarding downtime of infrastructure, restoration times vary considerably, with distribution transformers taking between 1–3 weeks to restore, while gas plant equipment may require 2–8 weeks. Substations, critical for power distribution, need 2–6 weeks for repairs, emphasizing extended service interruptions during flooding events. The perception of accountability for protecting infrastructure is mainly attributed to PHED (57.7%), followed by local government (14.8%) and state government (11.1%), indicating a reliance on institutional entities. Nonetheless, community-level initiatives appear to be limited, as 44.4% of respondents indicated they had taken no proactive steps. There is substantial endorsement for mitigation

methods, especially regarding the relocation of infrastructures (70.9%) and the establishment of early warning systems (90.5%). Nevertheless, a significant portion of participants perceived the local government's preparedness as inadequate or very inadequate (69.3%), reflecting discontent with current flood management strategies. The findings substantiate that damage to energy infrastructure from floods incurs considerable economic losses and extended downtime, greatly impacting livelihoods and service delivery. The lack of readiness and ineffective community interventions further intensify these effects, emphasizing the urgent need for enhanced infrastructure resilience and proactive flood management measures.

Discussion of the findings

Susceptibility of Power Infrastructure and Renewable Energy Installations to Flood Depth, Velocity, and Duration

Results presented in Table 2 indicate that energy infrastructure in ONELGA is extremely vulnerable to flooding. The prevalence of direct-loop gas plant supply (55.0%) and generator reliance (30.0%) highlights a notable dependence on decentralized and fossil-based energy sources, while grid electricity (12.0%) and solar power (3.0%) remain limited. This trend points to a weak and unresilient energy framework, especially in flood-prone areas where maintaining infrastructure is vital. The information revealing that 92.0% of participants faced power outages during floods strongly suggests that energy systems are very sensitive to factors such as flood depth, duration, and speed. This finding is consistent with the Intergovernmental Panel on Climate Change (IPCC, 2022), which noted that severe rainfall and flooding considerably disrupt electricity transmission and distribution systems, as well as off-grid energy sources, particularly in low-lying coastal areas and regions near rivers. Similarly, Jonkman (2005) identified that flooding often triggers a chain reaction of failures in critical infrastructures, including electricity, water, and transportation networks due to their physical interconnectedness. The elevated rates of transformer and substation destruction (82.0%) and toppled electricity poles (68.0%) reflect the conclusions of Egbenta and Ede (2018), who observed that flooding in urban and semi-urban areas of Nigeria leads to extensive damage to electrical distribution networks, especially those situated at low elevations or on the ground. The registered damage to solar energy systems (28.0%) also indicates that renewable energy installations are vulnerable to flooding risks, particularly when they are not situated at elevated heights or protected against floods. This aligns with the International Energy Agency (IEA, 2019), which indicated that distributed renewable power setups such as solar photovoltaic and battery storage systems face increasing climate hazards when built without adaptive design principles. The disruption of vital services—such as water provision (62.4%), communication (56.1%), healthcare (48.7%), and transport (44.4%)—illustrates significant interdependencies across sectors. Cutter, Burton, and Emrich (2010) stated that the interconnectedness of infrastructures magnifies the effects of disasters, as failures in one sector (electricity) can lead to successive breakdowns in water, health, and communication systems. The results affirm that the energy framework in ONELGA is extremely susceptible to the characteristics of floods (depth, duration, and velocity), impacting both traditional and renewable systems. This corresponds with Hallegatte (2012), who stressed that the exposure of infrastructures in developing nations significantly exacerbates disaster-related damages due to limited resilience and inadequate spatial planning.

Critical Interdependencies between Energy Infrastructure and Other Systems During Flood Events

Findings illustrated in Table 4.3 reveal strong socio-economic connections between energy infrastructure and other sectors such as household welfare, healthcare access, transportation, and economic activities. The notable percentage of households spending between ₦5,000 and over ₦50,000 on alternative energy indicates coping costs arising from energy failures. This observation is consistent with the World Bank (2021), which reported that households located in flood-affected areas often incur significant adaptive expenses during electricity outages, particularly in Sub-Saharan Africa, where the reliability of the grid is low.

Moreover, 52.4% of participants indicated damage to electronic devices as a result of floodwaters, illustrating direct susceptibility of assets. Merz et al. (2010) highlighted that disruptions in electricity caused by floods frequently result in secondary losses for households due to appliance destruction, particularly when backflow and water infiltration affect electrical systems. The statistic showing that 49.7% faced business or income losses underscores the economic link between energy provision and livelihoods. This aligns with the findings of Rentschler and Salhab (2020), who noted that power outages caused by floods have a disproportionate impact on informal workers and small enterprises, leading to decreased earnings and productivity. Likewise, Koks et al. (2019) evidenced that interruptions in electricity have ripple effects on transportation and economic structures, resulting in a decline in productivity across various sectors. The ONELGA findings further corroborate this, revealing that almost half of the respondents faced income disruption due to power failures. These results support the notion of systemic interconnections within infrastructure networks, demonstrating that energy systems are vital for the functionality of water, health, communication, and economic systems (Cutter et al., 2010). Hence, the repercussions of floods go beyond just physical damage to infrastructure, contributing to wider socio-economic instability.

Economic Losses and Downtime Resulting from Flood Damage to Energy Infrastructure

The results presented in Table 4.4 indicate that the economic ramifications of flood disruptions in ONELGA are substantial, with an average loss of ₦92,500 and a variation from ₦25,000 to ₦350,000. Merchants encountered the greatest losses, followed by the fishing and agricultural sectors, suggesting that informal and climate-sensitive livelihoods are the most impacted. This is in line with Hallegatte (2012), who pointed out that the effects of flooding tend to disproportionately impact informal economies due to their fragile financial situation and limited access to insurance. Additionally, the IPCC (2022) indicates that climate-related threats exacerbate economic disparities by heightening losses among disadvantaged work groups. The analysis of downtime indicates that restoration periods vary from 1 to 8 weeks based on the type of infrastructure, with gas plants requiring the most extensive recovery duration (2 to 8 weeks). This corresponds with the IEA (2019), which noted that recovery of energy systems post-flooding can be drawn out because of damage sustained in both generation and distribution systems, particularly in those that are poorly maintained. The belief that PHED holds the main responsibility for infrastructure protection (57.7%) signifies a reliance on institutional support, while the minimal community involvement (44.4% taking no action) highlights a weak capacity for local resilience (Wadi, et al, 2026). This further aligns with UNDRR (2020), which observed that disaster risk management in various developing areas is frequently centralized, with limited participation from local communities in mitigation efforts. The strong endorsement for early warning systems

(90.5%) and the relocation of infrastructure (70.9%) resonates with global frameworks for disaster risk reduction. According to UNDRR (2020), the effective implementation of early warning systems can significantly mitigate flood-related losses, whereas relocating crucial infrastructure from flood-risk areas is essential as an adaptation strategy. The viewpoint regarding inadequate preparedness of the LGA (69.3% rating it as poor or very poor) corresponds with findings from the World Bank (2021), which identified insufficient institutional readiness and poor drainage and spatial planning as key contributors to flood vulnerability in coastal communities in Nigeria.

Conclusion

The research indicates that the energy infrastructure within ONELGA is extremely vulnerable to flooding, which is defined by factors such as water depth, duration, and speed. Both traditional and sustainable energy sources face significant impacts, demonstrating that no energy option currently exhibits complete resilience. Additionally, the research reveals a significant reliance on energy systems among various socio-economic sectors, including health care, water distribution, communication, transport, and economic activities. Consequently, disruptions to energy during floods create a chain reaction, heightening the vulnerability of numerous sectors. Ultimately, the research finds that damage to energy infrastructure caused by floods results in considerable financial losses and extended periods of inactivity, especially impacting informal and vulnerable job sectors such as trading, fishing, and agriculture. Insufficient institutional preparedness and a lack of proactive community interventions exacerbate the situation, although there is strong public awareness and endorsement for mitigation initiatives like early warning systems and the relocation of infrastructure.

Recommendations

Considering the study's conclusions, the following suggestions are put forward:

1. Energy facilities, including transformers, substations, inverter systems, and solar setups, ought to be raised and designed to withstand flooding by employing robust engineering standards to minimize the risks associated with flood depth and duration.
2. It is essential to encourage the development of renewable energy systems that are resilient to climate change, especially elevated solar mini-grids and hybrid systems equipped with protective storage, to reduce reliance on vulnerable centralized energy sources.
3. Considering the substantial public backing (90.5%), it is crucial for governmental entities and disaster response organizations to enhance flood early warning systems by implementing real-time communication options to mitigate damage to both infrastructure and livelihoods.
4. Energy infrastructure situated in areas prone to flooding should be progressively moved to higher ground, with 70.9% of participants supporting this approach, aligning with global strategies for climate adaptation.

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