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Assessing Climate Resilience in Ecologically Vulnerable Areas in Ilaro, Ogun State

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Despite growing evidence of climate-related risks in Ilaro, Ogun State, Nigeria, there is limited localized research on how ecologically vulnerable communities cope with these challenges. This study, deploying both survey and GIS approaches, evaluated the climate resilience of ecologically vulnerable parts of Ilaro in Ogun State, Nigeria, and proposes locally tailored strategies to support sustainable development and strengthen community capacity to adapt. Using the Cochran formula, with a 6% margin of error and 95% confidence level, the total sample size calculated from the total population of buildings (15,933) identified within the ecologically disadvantaged areas was 263. Random sampling was employed with the use of a random table, involving a selection process that systematically checked the table either row by row, column by column, or diagonally to identify numbers within the range of 1 to 15,933. The study, among others, adopted logistic regression analysis to validate the fact that residents' vulnerability to climate hazards is significantly influenced by socio-economic and ecological factors. It canvassed an integrated approach, combining individual capabilities, ecological health, and institutional support, towards enhanced resilience and adaptive capacity.

Keywords: Climate, ecology, Ilaro, resilience, vulnerable, global warming

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Introduction

Globally, the need and relevance to assess vulnerability to climate change and natural hazards is based on the assumption that climate risks and actual losses caused by hazard events such as storms, floods, erosion or droughts are not solely a result of the climate hazard, but also determined by societal and economic preconditions that shape how people are prepared for or respond to such events (Akinde *et al.* 2025; Olapeju *et al*., 2025a; Birkmann, 2013; Cardona *et al*., 2012; Cutter *et al*., 2003; IPCC, 2012). Climate change presents a profound menace to the communities around the globe, including Ilaro town, which is located in Ogun State of Nigeria (Olapeju *et al*., 2025; Olapeju *et al*., 2025c). This not only impacts the physical structure of the house but economic and social structure of the city environment (Newbold, 2018). Climate change is now a major worldwide issue, and its regional consequences hit the ecologically sensitive communities. While it is important to focus on adaptive capacities, it is equally necessary to understand the critical points of vulnerabilities in local contexts. This is only possible when, according to Jabareen (2013), local knowledge on climate effects and resilience of the residents, which, in turn, restrains effective ways of planning and response, exists. The absence of documented data describing the climate vulnerability of cities, including Ilaro, essentially constrains quests to provide scientifically based evidence of climate-related risks within the moderately sized city.

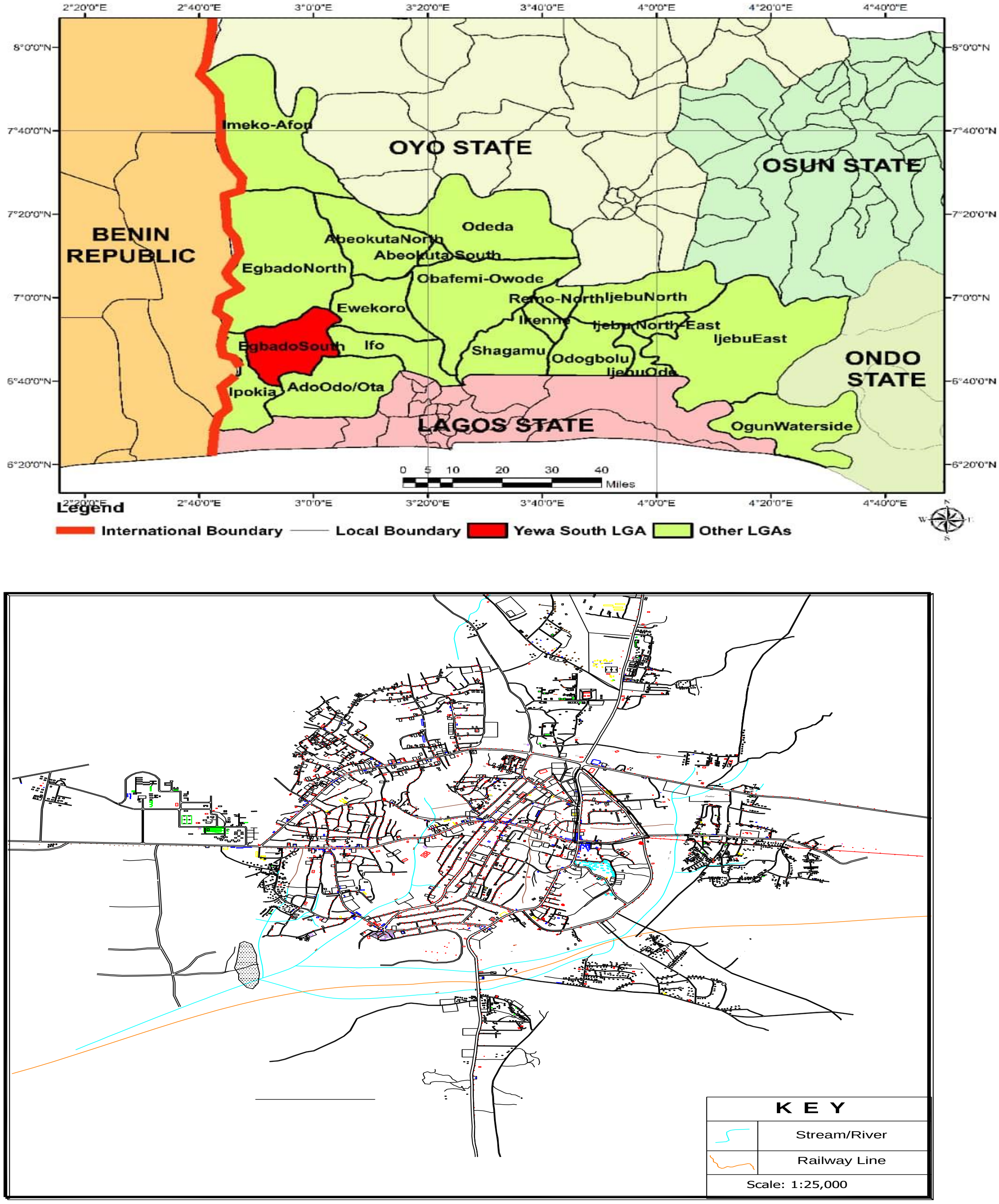
Studies have been conducted to evaluate the risk and resilience measures against climate in different regional contexts. For instance, Ozor *et al.* (2012) examined the climate challenges in the southeast of Nigeria and discovered that local people commonly experience drought and floods. In the same manner, Oladipo (2008) gave an overview of climate change effects on a national level but failed to give details on the local levels. Ogunbode *et al*. (2019) were concerned with southwestern Nigeria; nevertheless, their study lacked peculiar information that has bearing with the local climatic contexts of the study area.

Despite growing evidence of climate-related risks in Ilaro, Ogun State, there is limited localized research on how ecologically vulnerable communities cope with these challenges. Ilaro is the headquarters of Yewa South Local Government Area of Ogun State, Nigeria, which is experiencing the growing influence of environmental stressors, namely, floods, degradation of land, and random rainfall patterns. Climate-related events undermine local livelihoods, particularly among the households whose livelihoods depend on the use of natural resources, especially smallholder farmers and low-income households (Federal Ministry of Environment, 2014).

Most existing studies focus on broader regional trends, failing to capture the specific exposure, sensitivity, and adaptive capacity of smallholder households in Ilaro. This gap hinders the development of targeted resilience strategies and informed policy interventions that are tailored to the unique ecological and socioeconomic context of the area. This study aims to fill the research gap regarding the specific impacts of climate change on residents of Ilaro, Ogun State, as well as their vulnerabilities. It ultimately explored how several factors interact to influence the overall resilience of the community to climate change. This underscores the importance of a localized and in-depth analysis that goes beyond general observations to understand the unique context of Ilaro and its residents. The specific objectives of the study are to delineate ecologically disadvantaged areas within the study area, assess the climate-related events on residents and within ecological disadvantaged zones of the study area, and investigate the vulnerability of residents to climate change-related hazards in the study area.

Research Methodology

The study adopted both GIS and questionnaire methods to generate data within the study area, defined by coordinates 6.8954° N and 3.0126° E. To delineate the ecologically disadvantaged areas within the study area, a multi-criteria decision-making process was employed within a GIS environment using spatial data analysis.



Figures 1a and 1b: The Maps of Ogun State and Ilaro
Source: Department of Urban and Regional Planning, Federal Polytechnic Ilaro. (2024)

The total number of buildings in the ecological areas, estimated from the GIS analysis, which serves as the sample frame for the study, is 15,933. However, adopting a sample size calculator using William Cochran's method as explained in Johnson (2025): $N_0 = \frac{Z^2 \times P \times (1-P)}{e^2}$, where the precision level was deemed to be 6%, the confidence level considered 95%, and the estimated proportion considered at 0.5, the sample size estimated for the 15,933 aggregate building population was approximated to be 263. Moreover, random number tables were employed to select representatives for administering the questionnaire. These tables consist of digits arranged in random order. The selection process involves systematically checking the table either row by row, column by column, or diagonally, to identify numbers within the range of 1 to 15,933. A random starting point is chosen in the table. If a number falls outside the specified range or is a duplicate, it is skipped, and the process continues until 263 unique numbers are obtained. Each individual is selected independently, ensuring everyone has an equal probability of being chosen. The randomness of the selection derives from the method of using the random number table to pick specific individuals. Further, the instrument adopted a multi-item scale developed on a 5-point Likert scale that runs from strongly disagree to strongly agree. The questionnaires were self-administered, which offered the best means of engaging respondents and getting information in real time.

For the first objective, which involves delineating ecologically disadvantaged areas, GIS-based spatial analysis was employed. It employed the Analytical Hierarchical Process (AHP) to conduct a pairwise comparison in order to derive both external and internal weights for all criteria and classes within each criterion. The weighted linear combination method was then employed to integrate the criteria maps and produce a map displaying ecologically disadvantaged areas. AHP was adopted because it afforded a structured, systematic and transparent framework for assessing vulnerability (Sethuraman *et al*., 2024). Several spatial criteria were considered in identifying eco-friendly areas in this study, viz: Digital Elevation Model DEM, dew point, Land Use Land Cover (LULC), slope, soil, temperature, wind direction, wind speed, and water sources. Each of these criteria is converted into a raster and reclassified using the ArcGIS 10.6 weighted overlay tool. The spatial multicriteria evaluation method of the Analytic Hierarchy Process (AHP) (Tables 1 & 2) was developed to assign weight to each criterion under consideration. This evaluation method helps decision-makers facing a complex problem with multiple conflicting and subjective criteria based on the judgments of experts to derive priority scales. While weightings relied on expert judgments of professionals established in the literature (Frish *et al*., 2025; Saaty, 2008), the acceptability of the assigned weight was evaluated with a consistency check.

The climatic data were retrieved at the Ogun Osun River Basin Development Authority (O-ORBDA) at Abeokuta. The Inverse Distance Weighting (IDW) method was applied within the ArcGIS software to create rainfall and other climate maps. Additionally, elevation data was sourced from the Advanced Land Observing Satellite (ALOS) website. The area of interest was defined by drawing a box around it, and the data was downloaded in batches. The data were then uploaded into ArcGIS to prepare a slope map. The final step involved GIS-based multi-criteria Evaluation methodology using overlay operations.

Table 1: Ranking Criteria Comparison Matrix

Criteria	DEM	Dew	LULC	Slope	Soil	Temp	Wind Direction	Wind Speed	Disaster
DEM	1	8	4	6	4	7	10	9	3
Dew	0.1	1	3	4	3	4	8	6	2
LULC	1.0	0.3	1	8	5	8	10	10	4
Slope	3.0	1.0	0.1	1	5	5	10	7	3
Soil	1.0	8.0	1.0	0.2	1	8	10	10	4
Temp	0.1	1.0	5.0	1.0	0.1	1	9	6	2
Wind Direction	1.0	0.2	1.0	8.0	1.0	0.1	1	4	1
Wind Speed	5.0	1.0	0.1	1.0	9.0	1.0	0.3	1	2.0
Disaster	1.0	8.0	1.0	0.1	1.0	4.0	1.0	0.5	1
Sum	**13.25**	**28.53**	**16.25**	**29.31**	**29.13**	**38.11**	**59.25**	**53.5**	**22**

Table 2: Normalized Criteria Comparison Matrix (C)

Criteria	DEM	Dew	LULC	Slope	Soil	Temp	Wind Direction	Wind Speed	Disaster	Weight	% Weight
DEM	0.08	0.28	0.25	0.20	0.14	0.18	0.17	0.17	0.14	0.18	17.8
Dew	0.01	0.04	0.18	0.14	0.10	0.10	0.14	0.11	0.09	0.10	10.1
LULC	0.08	0.01	0.06	0.27	0.17	0.21	0.17	0.19	0.18	0.15	14.9
Slope	0.23	0.04	0.01	0.03	0.17	0.13	0.17	0.13	0.14	0.12	11.6

Soil	0.08	0.28	0.06	0.01	0.03	0.21	0.17	0.19	0.18	0.13	13.4
Temp	0.01	0.04	0.31	0.03	0.00	0.03	0.15	0.11	0.09	0.09	8.6
Wind Direction	0.08	0.01	0.06	0.27	0.03	0.00	0.02	0.07	0.05	0.07	6.6
Wind Speed	0.38	0.04	0.01	0.03	0.31	0.03	0.00	0.02	0.09	0.10	10.0
Disaster	0.08	0.28	0.06	0.00	0.03	0.10	0.02	0.01	0.05	0.07	7.0
Sum	1	1	1	1	1	1	1	1	1	1	100.00

Moreover, a consistency check was performed to validate the ranks of the criteria using the expressions in equations 1 & 2, respectively**.**

CI = (ʎ-n)/(n-1) Equation 1
CR = CI/RI Equation 2
Where;
ʎ = Eigen value = 1
n = Number of criteria = 9
RI = Random Index = 1.4537 (from the RI lookup table)
CI = Consistency index = -1.0
CR = Consistency Ratio = -0.69

The ranking of the criteria is consistent, since the CR is less than +0.1

The second objective adopted the Analysis of Variance to determine the relationship between climate-related and socioeconomic factors of the residents. However, logistic regression models were used to assess residents' vulnerability to climate change-related hazards.

Results and Discussion

Delineation of ecological areas

The first objective of this study was realized with the help of GIS. A GIS environment was used with the spatial data analysis of the multi-criteria decision-making approach to define these spots of ecological vulnerabilities. Such key requirements have been detected as water sources, land use/land cover, soil properties, wind direction, sky surface, temperature, dew point, wind speed, and slope (Ahmed *et al*., 2023; Ifediegwu, 2022; Ambarwulan *et al*., 2021).

The climatic data were retrieved at the Ogun Osun River Basin Development Authority (O-ORBDA) at Abeokuta. The Inverse Distance Weighting (IDW) method was applied within the ArcGIS software to create rainfall and other climate maps. Additionally, elevation data was sourced from the Advanced Land Observing Satellite (ALOS) website. The area of interest was defined by drawing a box around it, and the data were downloaded in batches. The data were then uploaded into ArcGIS to prepare a slope map.

The final step involved GIS-based multi-criteria evaluation methodology using overlay operations. The Analytical Hierarchical Process (AHP) was employed for a pairwise comparison to derive both external and internal weights for all criteria and classes within each criterion. The weighted linear combination method was used to integrate the criteria maps and produce a map displaying ecologically disadvantaged areas. These areas are classified, as shown in Table 3, into categories of Very Low, Low, Moderate, High, and Very High ecologically disadvantaged, representing 23.56%, 11.04%, 18.39%, 33.92%, and 13.08%, respectively, of the total study area. Areas classified as moderately, highly, and very highly ecologically disadvantaged most fall within erosion and flood-affected areas within new informal and unplanned settlements of the study area. It is pertinent to mention that while a lot of settlements within the core and dense parts of the study area are still ecologically damaged, they are the most represented when it comes to the implementation of mitigation measures in the form of roads and drainage developments inherent in the urban renewal programmes going on in the study area, which makes them have higher adaptive capacities.

Table 3: Areas and Percentages of Different Classes of Ecologically Disadvantaged Areas,

Class	Area m^2	% Areas
Low	26683716.41	23.56593
Very low	12495992.73	11.03593
Moderate	20826654.56	18.39322
High	38413607.29	33.92528
Very High	14810065.46	13.07963
Total	**113230036.5**	**100**

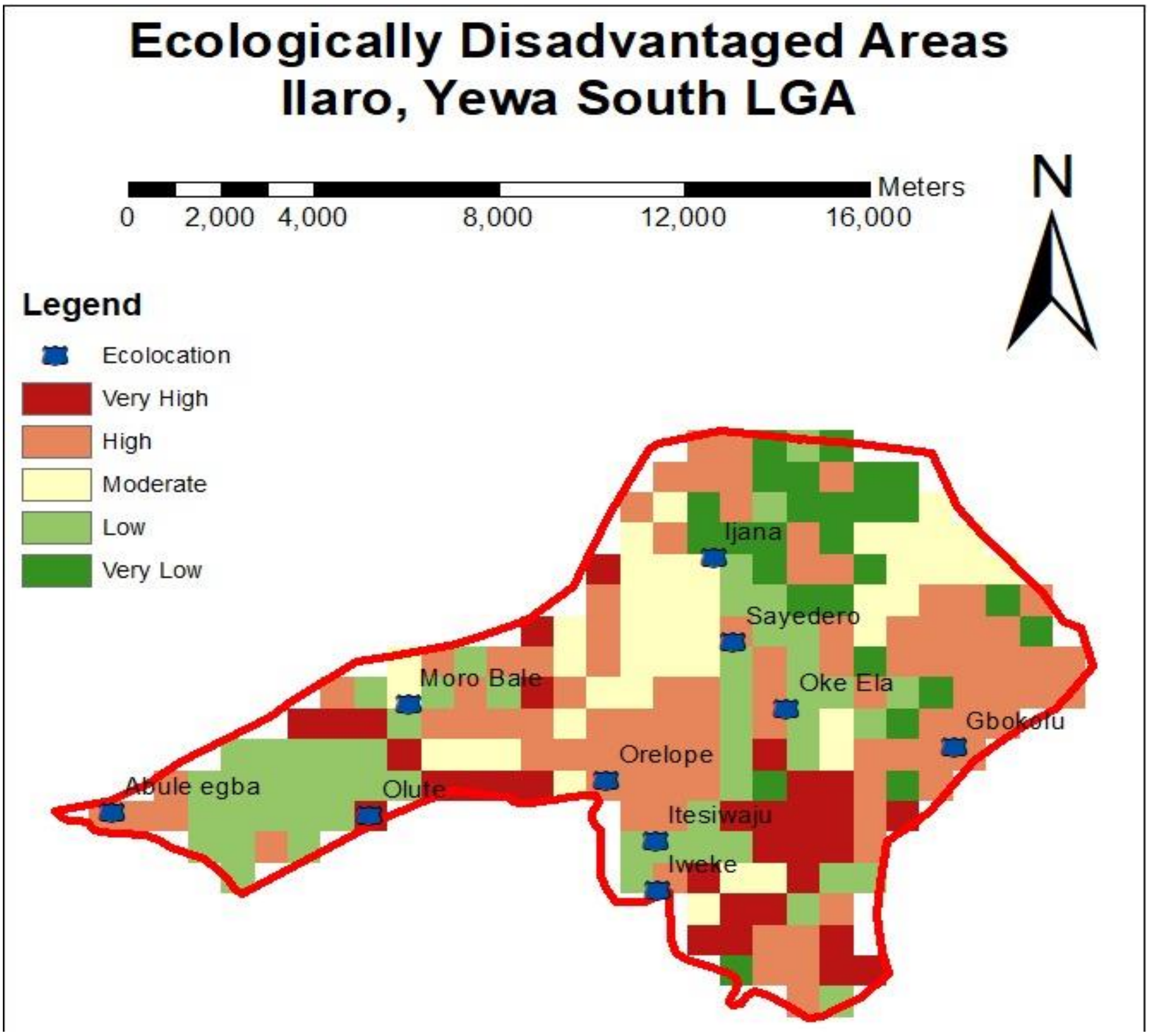


Figure 4: Ecologically Disadvantaged Areas within Ilaro

Climate-related events in the study area

The climate-related events in the study area include frequent flooding, soil erosion, drought, and land use. Out of the respondents, 44.8% perceive their environment as degraded**,** while 55.2% consider it moderately degraded**,** meaning that 100% acknowledge varying degrees of environmental stress. This consensus suggests that the area may be classified as ecologically disadvantaged, a term defined by the United Nations Environmental Programme (2019) as areas vulnerable to environmental degradation and climate change due to geographical, ecological, and socio-economic factors. Similar concerns are echoed by Edward and Hochard (2018) who identified less-favoured agricultural areas (LFAAs) and low-elevation coastal zones (LECZs) as particularly at risk. In developing regions, Daniel *et al*. (2023) linked such ecological fragility to mental health challenges, especially among smallholder farmers who face ecological grief due to the compounded stress of poverty, poor health, and low adaptive capacity in the face of climatic stressors. Furthermore, the role of interconnected climate systems and socio-economic exposure to environmental risks has been emphasized by Fuente and Williams (2022), who advocated for addressing sustainability challenges by accounting for demographic disparities and infrastructure deficits. As Knox *et al.* (2016) demonstrated in the context of African agriculture, structural inequalities in socio-economic conditions exacerbate the adverse effects of climate variability, including water-related hazards such as flooding. These perspectives collectively reinforce the need for context-specific climate adaptation strategies that consider residents' socio-economic profiles to effectively mitigate environmental risks like floods.

With respect to the relationship between climate-related events and socioeconomic factors, the results indicated that the level of **e**ducation and type of occupation predispose residents to climate risks such **as** flooding (47%)**,** soil erosion (59.5%)**,** and drought (29.8%), and land use change. These findings are consistent with the United Nations Environmental Programme (2019)**,** Edward and Hochard (2018)**,** and

Daniel *et al*. (2023), who stressed that socio-economic and ecological vulnerabilities intersect in ecologically disadvantaged regions. While age, gender, income, household size, and access to electricity do not consistently show significant associations, the impact of education and occupation remains clear across multiple climate-related stressors. This is an indicator of larger issues established by IPCC (2012) of a disproportionate socio-ecological effect of climate change on developing territories. It also supports the idea that context-specific steps of adaptation should be designed to pay more attention to the importance of human capital and the use of land (Sebastian & Dirk, 2023; Lin *et al*., 2018). This implies that there is a need to reduce climate vulnerability through specific education and livelihood measures.

Vulnerability of residents to climate change-related hazards

Vulnerability of residents to climate change-related hazards was measured by three important variables: ability to recover from climate events, health condition, and high-risk areas. The study reveals that 53.6% of households report a moderate ability to recover from climate events, while 26.2% indicate good recovery capacity. However, 20.3% (those reporting poor or very poor recovery) face significant challenges. These findings reflect broader patterns identified in global literature, where vulnerability is shaped not just by exposure to hazards, but by socio-economic factors like income, infrastructure, and access to resources, highlighted by Nurse *et al.* (2014); IPCC (2014); and Birkmann *et al*. (2013). Federal Ministry of Environment (2014) and Ebele and Emodi (2016) emphasised that in developing countries such as Nigeria, disparities in recovery capacity are more pronounced, particularly in high-risk areas like Ogun State, where erratic weather and poor infrastructure intensify impacts. Similar to global trends (Nicholls *et al*., 2018; Anderson & Bell, 2011), vulnerable groups face greater risks and prolonged recovery. These insights highlight the urgent need for targeted adaptation and resilience strategies for the most at-risk households.

Similarly, 64.3% of respondents reported that their health condition worsened during extreme weather events, while 35.7% do not experience any noticeable change. This indicates that extreme weather significantly impacts public health for the majority of households in the study area. The significant rate of health-related vulnerability indicates critical requirements in the sphere of climate-resistance of healthcare systems and population health control, particularly, in those regions being subjected to climate-related severe conditions regularly. This observation corresponds with the findings in other regions in the world, which highlight the health consequences of climate variability, especially in the developing world, where healthcare systems are not usually well developed (IPCC, 2014; Adger, 2006). Low-income households and older adults are particularly vulnerable as they lack access to medical resources and coping facilities (Fussel, 2007; O Neill & Ebi, 2009). It is also important to understand that urban heatwaves and flooding compound pre-existing ailments as they worsen the conditions in vulnerable populations, as confirmed by Satterthwaite *et al*. (2018) and Anderson and Bell (2011) as well.

Moreover, 59.5 percent of people had their homes in the area that was characterized by the risk, which may be close to the river or in a position with the risk of erosion, so 40.5 percent of the respondents do not. This exposure to most places prone to hazards contributes a lot to making these people more vulnerable to climate incidents such as flooding and soil erosion. It highlights that land-use planning, relocation assistance, and policies sensitive to risk should be enacted in these regions to decrease exposure and increase community resilience. This fact aligns with the notations of other scholars, such as Nicholls *et al*. (2018) and UN-Habitat (2015) which indicated that poorly planned urban growth and settlement in the ecologically sensitive or marginal lands increase risks of climate change, especially in the developing world. In the same way, the IPCC (2012) pointed out the fact that the closer to the dangerous area there is proper infrastructure or protection measures, the more consequences of climate change occur, the more intense. The aforementioned risks are further enhanced by environmental degradation and a lack of enforcement of the zoning rules, as observed by Uyigue and Agho (2007) and Federal Ministry of Environment (2014).

These findings align with the vulnerability framework defined by Adi *et al*. (2020) and Dunn and Hayes (2020), where Vulnerability (V) is a function of Exposure (E) and Sensitivity (S) divided by Adaptive Capacity (AC)**:** $V = (E \times S) / AC$**.** In the study area, empirical findings showed that high exposure, evidenced by 59.5% of households residing in hazard-prone areas, combined with high sensitivity, reflected in the 64.3% of respondents experiencing worsening health during extreme weather, significantly increases vulnerability. Moreover, limited adaptive capacity, as shown by the 20.3% of households with poor recovery ability, further intensifies climate risk. These results validate the vulnerability index model by Dunn and Hayes (2020) and Adi *et al*. (2020), highlighting the critical role of socio-economic and institutional factors in shaping outcomes. Ultimately, the study underscored the urgent need for targeted, context-specific adaptation strategies such as improved health systems, resilient infrastructure, income enhancement, and effective land-use planning to reduce vulnerability and build climate resilience in high-risk, low-capacity communities like those in Ilaro. The findings support Dunn and Hayes (2020) and Adi *et al*. (2020), emphasizing that socio-economic and institutional factors critically shape resilience outcomes.

Residents' vulnerability to climate hazards on socio-economic and ecological factors

As presented in Table 4, logistic regression was adopted to examine whether residents' vulnerability to climate hazards is not significantly influenced by socio-economic and ecological factors. The dependent variable in this analysis is "High risks," which has a code value of 1.00. This value signifies the reference threshold for resident vulnerability, understood as a state of high climate hazard risk. The findings of the regression analysis indicate that residents' vulnerability to climate hazards is significantly influenced by socio-economic and ecological factors. Notably, monthly income emerged as a critical determinant: individuals in the lowest income group (Income 1) were nearly 966 times more likely to be vulnerable (Exp(B) = 965.97**,** *p* = 0.000), while those in the moderate-income group (Income 2) were over 8 times more likely (Exp(B) = 8.11**, *p* = 0.015).** In contrast**,** high-income earners (Income 3) were 86% less likely to be vulnerable (Exp(B) = 0.143**, *p* =** 0.026**),** clearly showing an inverse relationship between income and vulnerability.

Education level also influenced vulnerability in a non-linear manner. Lower education (Education Level 1) reduced the odds of vulnerability by 90% (Exp(B) = 0.109, *p* = 0.007), and Education Level 2 by nearly 99% (Exp(B) = 0.013, *p* = 0.035). However, surprisingly, Education Level 3 (higher education) increased vulnerability more than 22 times (Exp(B) = 22.773, *p* = 0.047), possibly due to higher expectations, exposure, or responsibilities.

Access to electricity was another strong predictor: residents without electricity were over 1,000 times more likely to be vulnerable (B = 6.966, Exp(B) = 1059.86, *p* = 0.001), underscoring infrastructure as a core adaptive capacity component. Other variables, such as occupation (*p* < 0.001), were significant overall, but individual category data were unreliable due to extreme values and uniform *p*-values. Household size (Exp(B) = 4.244, *p* = 0.171) and land use activities (*p* = 0.199) were not statistically significant predictors, though they may still influence vulnerability contextually.

Table 4: Logistic Regression of Residents' Vulnerability to Climate Hazards on Socio-economic and Ecological Factors

Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 0	Constant	-.386	.128	9.030	1	.003	.680

Model Summary

Step	-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square
1	150.249[a]	.529	.715

Vulnerability of Residents to Climate Change-Related Hazards

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	Education Levels			15.659	3	.001	
	Education Levels (1)	-2.212	.816	7.341	1	.007	.109
	Education Levels (2)	-4.373	2.073	4.450	1	.035	.013
	Education Levels (3)	3.126	1.572	3.954	1	.047	22.773
	Occupation			36.165	4	.000	
	Occupation (1)	-3.679	18307.632	.000	1	1.000	.025
	Occupation (2)	16.514	11542.749	.000	1	.999	14862866.805
	Occupation (3)	20.972	11542.749	.000	1	.999	1281901720.031
	Occupation (4)	16.549	11542.749	.000	1	.999	15384209.223
	Monthly Income			17.181	3	.001	
	Monthly Income (1)	6.873	1.920	12.809	1	.000	965.966
	Monthly Income (2)	2.093	.864	5.868	1	.015	8.113
	Monthly Income (3)	-1.944	.875	4.936	1	.026	.143
	Household Size (1)	1.446	1.057	1.870	1	.171	4.244
	Electricity (Access to basic services) (1)	6.966	2.096	11.046	1	.001	1059.864
	Land use activities (1)	1.289	1.004	1.649	1	.199	3.629
	Constant	-27.105	11542.749	.000	1	.998	.000

Conclusion

The findings paint a nuanced picture of climate vulnerability and resilience in Ilaro, Ogun State. While the population demonstrates relatively high levels of education and income, significant vulnerabilities persist, particularly among lower-income groups, households with limited access to electricity, and residents in ecologically degraded zones. Education and income influence not only residents' exposure to climate hazards but also their capacity to adapt through informed decision-making and strategic planning. Ecological factors, especially soil conditions and geographic location, were found to be strong predictors of the frequency and severity of climate-related events. Interestingly, while education typically supports adaptation, the findings suggest that higher levels of education may correlate with greater vulnerability, possibly due to occupational risks in urbanized or exposed settings.

These insights reinforce the fact that climate resilience is not solely dependent on socio-economic status but is instead the product of complex interactions between individual capabilities, ecological health, and the effectiveness of institutional and infrastructural support. Though there have been improvements in core areas of the study area, where commendable urban renewal programmes were going, much still needed to be done by stakeholders such as the government and Community Development Associations (CDA) in closing the resilience gap, particularly by improving public infrastructure, regulatory enforcement, and localized climate response planning. This study could be improved by applying more precise Machine Learning Algorithms for predicting vulnerability patterns more accurately.

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