Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 18, Issue, 08, pp.38004-38010, August, 2026
DOI: https://doi.org/10.24941/ijcr.50822.08.2026

ISSN: 0975-833X

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

CLIMATIC VARIABILITY AND TRAUMA AMONG POPULATIONS IN THE SEME PODJI DISTRICT (BENIN)

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ARTICLE INFO

Article History:
Received 17th May, 2026
Received in revised form
20th June, 2026
Accepted 27th July, 2026
Published online 31st August, 2026

Keywords:
Climate variability, trauma, public health, Sèmè-Podji, climate correlation, community resilience

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ABSTRACT

Increasing climate variability in West Africa, and more specifically in Benin, poses serious challenges to vulnerable populations. The Sèmè-Podjidistrict , exposed to extreme weather events such as droughts and floods, suffers direct impacts on the health and well-being of its inhabitants. These climate hazards generate physical, psychological, social, and economic trauma. This study aims to analyze the relationship between this climate variability and the trauma experienced by the local population in order to propose courses of action adapted to the specific context. The methodological approach relies on the analysis of climatological data (rainfall, temperature, relative humidity) covering the period 1983–2022, as well as epidemiological data on trauma cases collected between 2008 and 2022 in the Porto-Novo- Aguégué - Sèmè-Podji health district . A sample of 384 people from the six villages in the district was also surveyed according to age and residence criteria. Statistical analysis was performed using Pearson's correlation coefficient to measure the links between climatic parameters and trauma. The results reveal a general downward trend in the annual number of injuries, with a peak in 2008 (709 cases) and stabilization at around 150–280 cases after 2013. The monthly distribution shows peaks in April (298 cases) and December (325 cases). A moderate but significant negative correlation ($r = -0.592$; $p = 0.0426$) was observed between monthly rainfall and injuries, suggesting that heavy rainfall limits certain risky activities. Average temperature showed a moderate positive correlation ($r = 0.459$; $p = 0.1337$), while relative humidity showed a weak but non-significant negative correlation ($r = -0.251$; $p = 0.4319$). These results confirm the importance of integrating climatic parameters into the management and prevention of injuries in this area.

Citation: **BOKO Nouvêwa Patrice Maximilien. *2026.*** "Climatic variability and trauma among populations in the seme podji district (benin)". ***International Journal of Current Research, 18, (08), 38004-38010.***

INTRODUCTION

Climate change is leading to increasing instability in weather patterns, particularly affecting the most vulnerable areas, notably West Africa (N. Watts *et al.,* 2017, p. 585). Benin, located in the tropics, regularly faces extreme weather events (prolonged drought and/or flooding), which impact the daily lives of local populations (P. Cianconi *et al., 2020, p. 3). The* Sèmè-Podjidistrict , located in a coastal area with high population density and widespread agriculture, is vulnerable to these climatic hazards. This instability results in economic losses and causes various forms of physical, psychological, and social trauma (H. Berry *et al.* , 2018, p. 284). Indeed, the psychological consequences of repeated exposure to extreme weather events pose significant challenges to mental health (S. Clayton *et al.,* 2014, p. 15). It is therefore essential to better understand these interactions in order to develop resilience and adaptation strategies that are truly rooted in local realities (K. Hayes *et al.,* 2018, p. 8). This research aims to highlight the links between climate variability and the traumas suffered by the populations of Sèmè-Podji , with a view to proposing concrete and appropriate measures to address these challenges in the near future.

Geographical location of the study area: The district of Sèmè-Podji is one of the districts of the commune of Sèmè-Podji . It is located between 6°21' and 6°24' North latitude and 2°34' and 2°38' East longitude. The district of Sèmè-Podji is bordered to the northeast by the district of Djéregbé , to the northwest by the district of Aholouyèmè , to the south by the Atlantic Ocean, to the east by the district of Tohouè , and to the west by the district of Ekpè . It covers an area of 32.86 km². The district of Sèmè-Podji is characterized by a sub-equatorial climate. The climate is marked by two dry seasons, from December to March and from August to September, and two rainy seasons (April to July and October to November). The average temperature is approximately 27°C with high relative humidity. Due to its geographical location, it is influenced by coastal winds, which often create cyclical disturbances that make the district of Sèmè-Podji, and the commune in general, one of the wettest areas in southern Benin, with an average annual rainfall exceeding 1100 mm (Sèmè-Podji PDC). Indeed, thanks to the proximity of the Atlantic Ocean, the air is generally laden with humidity (on average 75°C relative humidity in the dry season and 90% on average in the rainy season) PDC Sémè-Podji).

Methodological approach

Data used and sources

The data used for this study consists essentially of three data points. These are: climatological data (rainfall, temperature and relative humidity) ranging from 1983 to 2022 and are extracted from the Benin Meteorological database. Epidemiological data (trauma cases) for the Sèmè-Podjidistrict , from 2008 to 2022, were collected at the Porto-Novo - Aguégué - Sèmè-Podji Health Zone (ZS-PAS). The following table summarizes the types of trauma considered in this study.

The table provides a clear overview of the different types of trauma that climate variability can cause to populations. It highlights that the impacts of climate are not limited to material or physical damage, but also affect psychological, economic, nutritional, social, and health dimensions. This holistic approach allows us to understand the complexity of climate effects on the health and quality of life of communities. It should also be noted that this data has been supplemented by the results of field surveys and documentary research.

Sampling: The selection of individuals interviewed for this study is based on two cumulative criteria:

- Be at least 18 years old
- Living in the community for the past 10 years;

It took into account the 6 villages in the district. The sample size was determined using the following equation:

$$X = \frac{t^2 * p * (1-p)}{e^2}$$

X = the sample size
t = reduced deviation corresponding to a sampling rate of 95% (t = 1.96)
p = n/N ; with p = Proportion of the sampled population;
n = size of the population meeting the predefined criteria and N = size of the population of the district of Sèmè-Podji . Thus we have: p = n/N = 11537 / 23636 = 0.48 or 48% e^2 = desired precision equal to 5%;
1-p = 1-48 = 52%; X = $((1.96)^2 \times 0.48 \times 0.52)) / 0.05^2$ = 383.54, therefore X = 384

Depending on the size of the borough, 384 people will be surveyed.

Data Processing: As part of the climatological data processing, the arithmetic mean was calculated using Excel. This mean combines the following climatic parameters: temperature, rainfall, and relative humidity. It is obtained using the following equation:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} xi$$

Where :n is the total number of variables; xi is the monthly value of the different variables. The monthly averages define the central value and allow for a quick and comprehensive simplification. The link between the studied climatic parameters and the various conditions considered was established using Pearson's correlation formula. The resulting coefficient allows us to assess the degree of dependence between the two variables. The mathematical formula is expressed as follows:

$$r = \frac{\mathrm{cov}(x, y)}{\sigma x\ \sigma y}$$

Where: Cov (X, Y): covariance of X, Y; σx: standard deviation of X; σy: standard deviation of Y

This coefficient, which varies between -1 and +1, has been interpreted according to the following grid:

- if | r | = 1, then there is a total dependence between the two characteristics studied;
- if r = 0, then the two characteristics studied are independent;
- if |r| < 1, the dependence is said to be partial;
- if 0.6 < |r| < 1, then the two characteristics studied evolve in the same way and the evolution of one influences the other. In this case, the two characteristics are strongly correlated;
- If 0.3 < |r| < 0.6, the two characteristics evolve in approximately the same way. In this case, they are moderately correlated;
- If 0 <|r| < 0.3, the two characteristics are independent.

Therefore, there is no correlation between the two characteristics studied. Regarding the health data, its processing was also made possible thanks to Excel software. It allowed us to create the tables and graphs.

RESULTS AND DISCUSSION

Evolution of trauma cases in the district of Sèmè-Podji: Field surveys conducted among the population of Sèmè-Podji, combined with information gathered during an interview with the head of the Sèmè -Podji Community Health Center (CSCom), revealed that approximately 78% of complaints are due to illnesses caused by climate variability. These include malaria, dermatological conditions, trauma, gastrointestinal infections, and acute respiratory infections (ARIs). Figure 1 illustrates the annual evolution of trauma cases in the Sèmè-Podji district over the period 2008-2022, highlighting the main trends. An examination of the figure representing the annual evolution of trauma cases in the Sèmè-Podji district over the period 2008-2022 reveals an overall downward trend. In 2008, the number of recorded cases was particularly high, reaching 709, marking a significant peak that could be associated with an exceptional event or specific conditions that year. Subsequently, a gradual and relatively steady decrease in the number of cases is observed, with some minor fluctuations. From 2009 to 2013, cases fluctuated between approximately 169 and 413, indicating a period of instability with significant

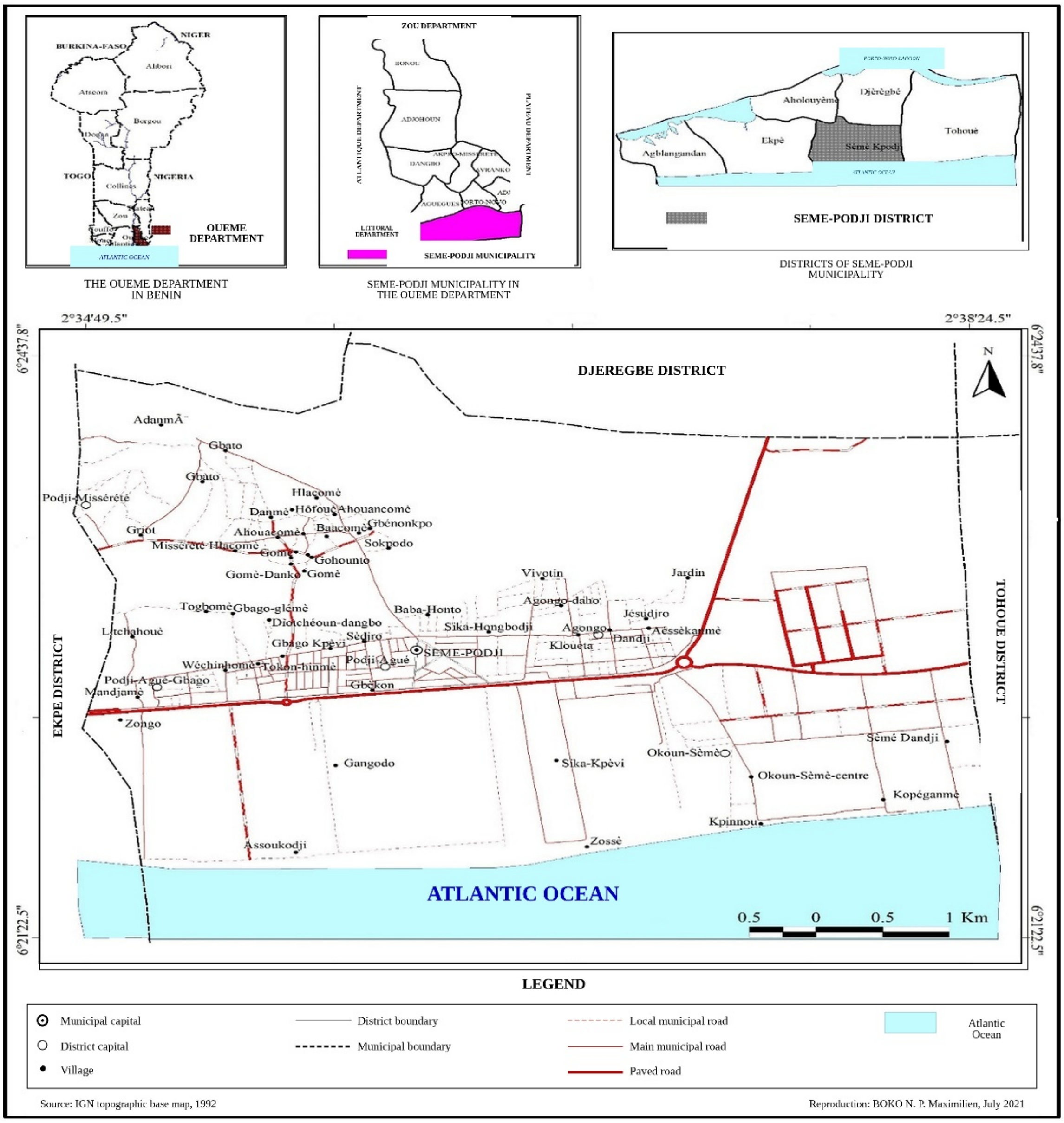


Figure 1. Geographical location of the Sèmè-Podji district

Table 1. Summary of the types of trauma identified

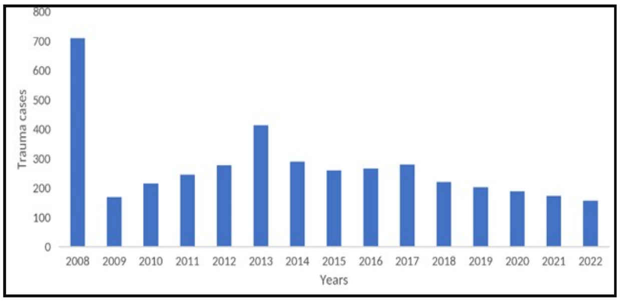
Type of trauma	Causes related to climate variability	Demonstrations	Potential consequences
Physical trauma	Floods, storms, landslides, droughts	Injuries, fractures, drownings, accidents related to natural disasters	Deaths, disabilities, prolonged hospitalizations
Psychological trauma	Stress due to climate disasters, loss of livelihoods, anxiety related to food insecurity	Anxiety, depression, post-traumatic stress disorder (PTSD), eco-anxiety	Mental health problems, social isolation, decreased quality of life
Economic trauma	Crop losses, infrastructure destruction, seasonal unemployment	Loss of income, economic insecurity, forced migration	Increased poverty, food insecurity, social tensions
Nutritional trauma	Food insecurity linked to climate hazards	Malnutrition, deficiencies, developmental disorders	Weakened immune system, infant mortality, cognitive delays
Social trauma	Forced displacement, resource-related conflicts	Breakdown of community ties, inter-community conflicts	Social instability, violence, loss of social capital
Health trauma	Spread of diseases linked to climatic conditions (e.g., post-flood epidemics)	Infectious diseases, worsening of chronic diseases	Excess mortality, overload of healthcare systems

Source :A. Walinski et al., 2023 and field survey, October 2024

Table II. Distribution of the different socio-professional groups surveyed

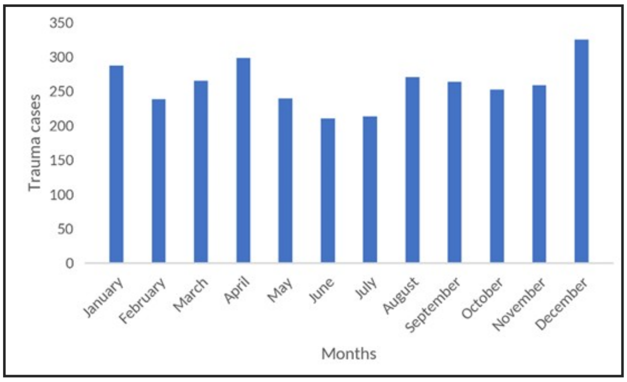
Group of socio-professional individuals surveyed	Number of people surveyed
Market gardeners	91
Merchants	90
Students	182
Health workers	12
Local agents	3
Others (zemdjan man, hairdresser…)	96
Total	**384**

Sources: Data from field surveys; November 2020



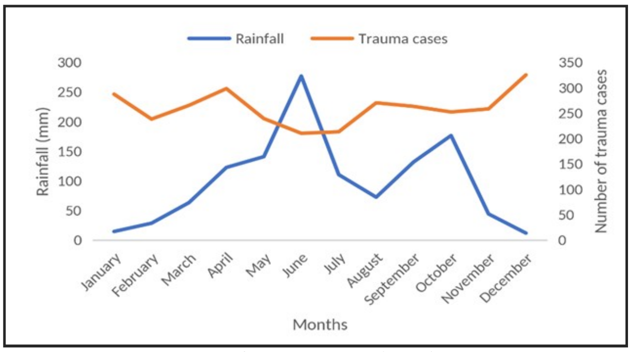
Source: Data from the ZS-PAS

Figure 2. Annual evolution of trauma cases in the Sèmè-Podji district



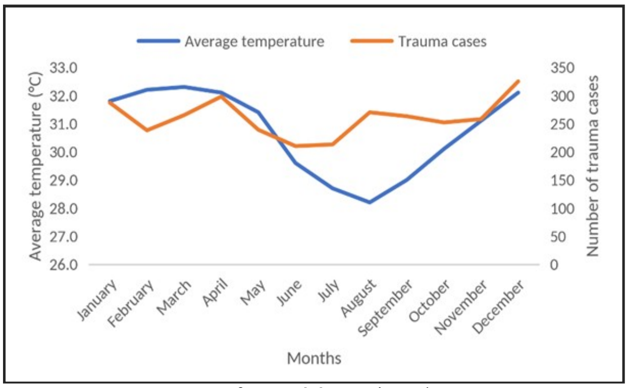
Source: Data from the ZS-PAS

Figure 3. Monthly distribution of trauma cases in the Sèmè-Podji district



Source: Data from Météo-Benin and ZS-PAS

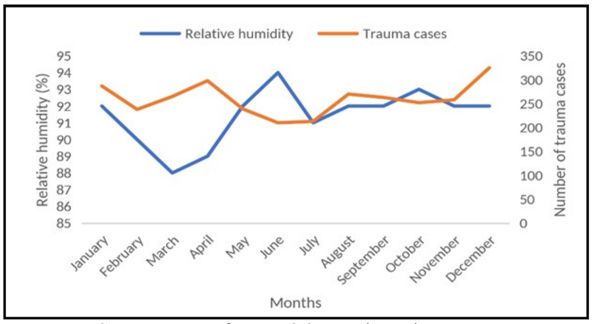
Figure 4. Inter-monthly evolution of trauma cases according to rainfall levels



Source: Data from Météo-Benin and ZS-PAS

Figure 5. Monthly relationship between rainfall and trauma cases in Sèmè-Podji

year-to-year variations. After 2013, the number of injuries tended to stabilize around a lower range, between 150 and 280 cases annually.



Source : Data from Météo-Benin and ZS-PAS

Figure 6. Monthly relationship between relative humidity and trauma cases in Sèmè-Podji

This long-term decrease may suggest several hypotheses, including improved prevention measures, strengthened healthcare infrastructure, or population adaptation to the risks associated with climate variability. It also reflects changes in data collection and reporting methods. It would be relevant to cross-reference this trend with climate data over the same period to identify potential links between climate variability and fluctuations in trauma cases. Further statistical analysis would validate these correlations and shed light on the explanatory factors.

Figure 2 presents the monthly distribution of trauma cases in Sèmè-Podji , revealing seasonal variations throughout the year. Analysis of the figure showing the monthly distribution of trauma cases in the Sèmè-Podji district reveals marked seasonal variations. The number of cases fluctuates throughout the year, with significant peaks in April (298 cases) and December (325 cases), which represent the months with the highest occurrences. These peaks are associated with specific climatic phenomena, such as seasonal transitions or extreme weather events (heavy rainfall, flooding), which can increase the risk of accidents and injuries. Indeed, in tropical regions like Sèmè-Podji , April often marks the end of the dry season and the beginning of the rainy season, a period during which infrastructure and travel conditions can deteriorate. Conversely, June (210 cases) and July (213 cases) recorded the lowest numbers, reflecting a stabilization of climatic conditions and human activity, thus reducing exposure to risk. The relatively even distribution across the other months, with cases fluctuating between 239 and 270, suggests a consistent pattern of incidents linked to everyday or socio-economic factors, compounded by seasonal climatic variations.

This analysis encourages further investigation into the relationship between monthly fluctuations in trauma and period-specific climate data, in order to better target preventive actions and emergency interventions.

Correlation between trauma cases and some climatic parameters in the Sèmè-Podji district

Rainfall amounts and evolution of trauma cases

Figure 4 relates monthly rainfall to cases of trauma, allowing observation of the potential effects of rainfall on the occurrence of trauma. Analysis of the figure shows that the months with the highest rainfall, namely June (276.61 mm), October (176.26 mm), and May (140.61 mm), do not coincide with the highest peaks in trauma cases. On the contrary, June recorded one of the lowest numbers of trauma cases (210).

This trend suggests that heavy rainfall limits certain risky activities, thus reducing the occurrence of trauma. In contrast, months like December (11.64 mm) and April (122.42 mm) show high levels of trauma (325 and 298 cases respectively) despite low to moderate rainfall, indicating that factors other than just the amount of rain influence the frequency of trauma. Thus, the figure illustrates that the relationship between rainfall and trauma cases is complex and non-linear, highlighting the importance of jointly analyzing other climatic and socio-economic parameters to understand trauma dynamics in the field. The correlation coefficient obtained for these two variables is r = -0.59. Since 0.3 <r and r< 0.6, the two variables are moderately correlated.

Average temperatures and evolution of trauma cases

Figure 5 illustrates the relationship between average monthly temperature and the number of trauma cases, suggesting a possible influence of thermal variations. Analysis of the figure shows an interesting trend between the average monthly temperature and the number of trauma cases in the Sèmè-Podjidistrict . It is observed that the months with the highest temperatures, particularly December (32.1°C), April (32.1°C) and March (32.4°C), also correspond to significant peaks in trauma cases, with 325, 298 and 265 cases respectively. This correlation suggests that high temperatures could increase the risk of injuries, possibly due to greater exposure to hazards related to physical activities, traffic conditions, or social phenomena favored by heat. Conversely, months with lower temperatures, such as August (28.2°C) and July (28.7°C), generally saw lower numbers of injuries (270 and 213 cases, respectively). This decrease reflects either less risky activity or a greater tolerance to milder weather conditions. Thus, the figure highlights a positive relationship between average temperature and the frequency of injuries, indicating that heat waves could play an aggravating role in the occurrence of accidents or injuries. The correlation coefficient for these two variables is r = 0.45. It falls within the range of 0.3 < |r| < 0.6, meaning that the two variables are moderately correlated.

Relative humidity and the evolution of trauma cases

Figure 6 analyzes the association between monthly relative humidity and trauma cases, examining the impact of this climatic parameter on the frequency of trauma. Analysis of the figure shows that relative humidity remains relatively stable throughout the year, fluctuating between 88% and 94%. This small variation does not appear to directly correspond to fluctuations in the number of monthly trauma cases. For example, the months with the highest humidity levels, such as June (94%) and October (93%), do not show the highest peaks in trauma cases (210 and 252 cases, respectively). Similarly, months with slightly lower humidity, such as March (88%) and April (89%), record higher rates of trauma cases (265 and 298 cases). This stability in relative humidity means that it plays a less decisive role in the monthly variation of injuries in Sèmè-Podji . However, its interaction with other climatic factors, particularly temperature, contributes to modulating the perception of thermal comfort and indirectly influences risky behaviors. Thus, although relative humidity alone does not explain the dynamics of trauma, it remains an important component of the overall bioclimatic context to consider in a multifactorial analysis. The correlation coefficient obtained is r = -0.20, which means that the two variables are not correlated, since 0 < |r| < 0.3.

Periods of heavy rain and high temperatures are when the most trauma-related complaints are recorded. The causes of this prevalence are due to several factors, including flooding that leads to crop losses, periods of prolonged drought that also cause crop losses during the dry seasons, and even disruptions to farmers' agricultural calendars.

Table III. Pearson correlation coefficients between climatic parameters and trauma cases

	Correlation coefficient (r)	P-value
Variable	**Trauma cases**	
Rainfall	-0.592 (ǀ r ǀ = 0.59)	0.0426 *
Average temperature	0.459	0.1337
Relative humidity	-0.251 (ǀ r ǀ = 0.25)	0.4319

Source:

Table III summarizes the results of the Pearson correlation test between climatic parameters and monthly trauma cases, identifying statistically significant relationships. The Pearson correlation coefficient table highlights the statistical relationships between monthly trauma cases and three climatic parameters: rainfall, average temperature, and relative humidity. A moderate and statistically significant negative correlation was observed between rainfall and trauma cases (r = -0.592, p = 0.0426). This relationship indicates that heavier rainfall is associated with a decrease in the number of recorded traumas. This phenomenon can be explained by a reduction in outdoor activities or a change in behavior during periods of heavy rainfall, thus limiting exposure to the risk of injury and accidents. In contrast, average temperature showed a moderate positive correlation (r = 0.459) with trauma cases, although this association was not statistically significant (p = 0.1337).

This trend suggests that an increase in temperature could be linked to a rise in trauma, likely due to greater exposure to risky situations in warmer conditions. However, the lack of statistical significance warrants caution in interpreting this link. Finally, relative humidity showed a weak negative correlation (r = -0.251) with trauma cases, but this correlation was not statistically significant (p = 0.4319). This weak relationship suggests that relative humidity, within the observed range, is not a determining factor in the monthly variation of trauma cases. These results indicate that, among the climatic parameters studied, rainfall is the factor with the strongest and most significant relationship to the frequency of injuries in Sèmè-Podji . They highlight the importance of integrating rainfall data into injury risk assessments and preventive measure planning. Furthermore, the observed trend with average temperature warrants further investigation using a multidimensional approach.

DISCUSSION OF RESULTS

The results obtained confirm that climate variability has a significant impact on the health and safety of the population in the Sèmè-Podjidistrict , particularly on the frequency of injuries. The overall decrease in the annual number of injury cases observed since 2008 could reflect improved healthcare or behavioral adaptations by the population in response to climate risks, but also changes in data collection methods (H. Berry *et al.,* 2018, p. 284). The strong negative and statistically significant correlation between rainfall and trauma cases (r = -0.592; p = 0.0426) indicates that heavy rainfall can reduce the occurrence of accidents. This observation is explained by a limitation of outdoor activities during periods of heavy rain, thus reducing exposure to risks (P. Cianconi) *.et al.,* 2020, p. 3). This finding is consistent with other studies that highlight that human behaviors adapt to weather conditions, modifying exposure risks (S. Clayton *et al.,* 2014, p. 15). In contrast, average temperature showed a moderate positive correlation with injuries, although not statistically significant ($r = 0.459$; $p = 0.1337$). This trend suggests that high temperatures, frequently recorded during months with peak injury rates, could encourage riskier behaviors, such as strenuous physical activity, increased travel, or social phenomena exacerbated by the heat (K. Hayes *et al.,* 2018, p. 8). However, this relationship requires further investigation with more comprehensive data and a multidimensional analysis incorporating socioeconomic variables.

The weak negative correlation between relative humidity and injuries ($r = -0.251$; $p = 0.4319$) indicates that this climatic parameter, which is relatively stable throughout the year, does not directly influence the monthly variation in injury cases. However, its interaction with other factors, particularly temperature, contributes to the modulation of thermal comfort and could indirectly affect risk-related behaviors (N. Watts et al., 2017, p. 585). These results confirm the need to adopt an integrated and multisectoral approach to managing risks related to climate variability. The complexity of the interactions between climatic factors, human behavior, and socio-economic vulnerabilities must be taken into account to strengthen prevention and adaptation strategies (A. Walinski) *.et al.,* 2023, p. 118). Finally, the psychological and social dimensions of climate trauma, particularly post-traumatic stress and eco-anxiety, although not directly measured in this study, constitute a major issue to be integrated into future public health policies (H. Berry *et al.,* 2018, p. 286; S. Clayton *et al.,* 2014, p. 15). Taking these factors into account is essential to ensure the long-term resilience of populations to climate change.

CONCLUSION

The study conducted on climate variability and injuries in the Sèmè-Podji district highlights the close links between fluctuations in weather conditions and the physical, psychological, and social health of local populations. The results show that while cases of injury tend to decrease overall over the observed period, seasonal and climatic variations continue to influence their frequency. In particular, the significant correlation between rainfall and the reduction in injuries underscores the direct impact of precipitation on risky behaviors.

Average temperature, although moderately correlated, also appears to play a role in the increase in incidents, while relative humidity seems less significant in this context. These findings call for greater consideration of climate parameters in health risk management and the implementation of resilience strategies tailored to local conditions. It is therefore essential to integrate this data into public policies to better anticipate, prevent, and mitigate the effects of climate hazards on the population. Furthermore, a multidimensional approach and further research are needed to deepen our understanding of the underlying mechanisms and optimize responses to the challenges posed by climate variability in Sèmè-Podjiand elsewhere in Benin.

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