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To Evaluate the Impact of Seasonal Weather Patterns on Suspected Typhoid Outbreaks in Rural Fiji from 2015 to 2021

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This study evaluates the impact of seasonal weather patterns, including rainfall, flooding, droughts, and tropical cyclones, on the prevalence of suspected typhoid cases in rural Fiji from 2015 to 2021. By analyzing secondary data sourced only from government annual reports and climatological summaries, this research identifies critical environmental drivers of typhoid outbreaks and explores their implications for public health strategies.

The study employs statistical methods such as correlation, regression, and ANOVA to establish relationships between climate variables and typhoid incidence. The findings highlight that minimum temperature has the strongest correlation with typhoid cases, while extreme weather events, particularly cyclones and floods, exacerbate the prevalence of the disease. Conversely, drought years were associated with lower case numbers, reflecting reduced waterborne exposure during such periods.

The results underscore the urgent need for climate-resilient water and sanitation infrastructure and proactive public health interventions tailored to Fiji's unique climatic and geographical context. Recommendations include the integration of predictive climate-health models, improved disease surveillance, and targeted community awareness campaigns. This research contributes to understanding the interplay between climate variability and infectious diseases in small island developing states, emphasizing the importance of adaptive strategies in mitigating the health impacts of climate change.

Keywords: Typhoid, Fiji, seasonal weather patterns, climate variability, public health, waterborne diseases.

Introduction

Waterborne diseases, particularly typhoid fever, pose a significant public health concern in many developing nations, including Fiji. This study explores the intersection of climatic conditions and public health by evaluating the impact of seasonal weather patterns—rainfall, flooding, droughts, and tropical cyclones—on suspected typhoid outbreaks in rural Fiji between 2015 and 2021. This investigation is critical for addressing both environmental and public health challenges that threaten the wellbeing of rural communities.

The linkage between climate variability and disease outbreaks has long been established, but understanding its localized impacts in Fiji, a Pacific island nation uniquely vulnerable to extreme weather events, remains underexplored. Fiji's tropical climate and reliance on natural water sources make it particularly susceptible to disruptions in water quality during extreme weather, increasing the risk of waterborne diseases such as typhoid. Despite existing public health interventions, rural Fiji continues to report substantial numbers of typhoid cases, particularly in years marked by severe weather events.

This study adopts a mixed-methods approach, incorporating quantitative statistical analysis and qualitative assessments to provide a comprehensive understanding of typhoid fever dynamics in the context of Fiji's rural settings. The methodology focuses on leveraging existing climatic and epidemiological data to identify trends, correlations, and key drivers of disease outbreaks, while ensuring the findings remain grounded in the local realities of resource-limited settings. Tools such as regression analysis, ANOVA, and correlation techniques were employed to investigate the influence of rainfall and temperature variability on typhoid incidence, alongside qualitative insights from thematic observations.

The research contributes to the global discourse on climate-resilient health systems by offering actionable insights for Fiji. Beyond examining the influence of weather patterns, the study identifies gaps in water and sanitation infrastructure that exacerbate disease risks in non-extreme weather conditions. Furthermore, it highlights the importance of integrating climate adaptation strategies within public health frameworks to mitigate the impact of climate variability on vulnerable populations.

I. Method

The research methodology forms a critical foundation for investigating the impact of seasonal weather patterns on suspected typhoid outbreaks in rural Fiji from 2015 to 2021. The study is structured according to Creswell's framework of research methods (Creswell, 2014) and Saunders' Research Onion model (Saunders, Lewis & Thornhill, 2009), which collectively provide a comprehensive approach for selecting suitable methodological layers, from philosophical foundations to data collection and analysis.

Creswell's research framework is instrumental in clarifying the logical alignment between the research questions, methodological approach, and research objectives. Creswell suggests that research methodology should closely reflect the nature of the study's questions and objectives, guiding decisions on quantitative versus qualitative approaches and influencing data collection and analysis techniques. Given the study's emphasis on understanding correlations between quantifiable environmental factors (such as rainfall, droughts, and tropical cyclones) and typhoid incidence, a quantitative approach is most appropriate.

Saunders' Research Onion model offers a structured, layered methodology. This model is particularly relevant for exploring the relationships between environmental variables and health outcomes, as each "layer" of the Research Onion can be tailored to address different aspects of the study. The Onion model begins with the selection of a philosophical stance, then moves through research approaches, strategies, choices, time horizons, and, finally, data collection techniques. Each layer will be discussed in detail, justifying the choice of positivism as a guiding philosophy, the quantitative and longitudinal approach, and specific techniques for analyzing secondary data.

This chapter will thus outline each methodological choice and reflect on its appropriateness, ensuring alignment with the research objectives of identifying correlations between seasonal weather events and typhoid prevalence in rural Fiji

Philosophy: Positivism

The philosophical foundation of this study is rooted in positivism. Positivism is a paradigm focused on objective reality and observable facts, making it ideal for research that aims to uncover measurable relationships (Saunders et al., 2009). Positivist research relies on empirical evidence, often gathered through structured data collection and statistical analysis, aligning well with this study's focus on analyzing quantitative data from secondary sources. By adopting a positivist stance, the research aims to maintain objectivity in evaluating the impact of weather patterns on typhoid incidence.

Approach: Deductive

The deductive approach is employed for this research, as it involves developing hypotheses based on existing theories and then testing them with empirical data (Bryman, 2016). This approach is particularly suitable when examining correlations between predefined variables, such as seasonal weather patterns and typhoid outbreaks. The study utilizes secondary data, which is analyzed to test assumptions about the relationship between environmental factors and disease prevalence.

Strategy: Quantitative Analysis

Given the quantitative nature of the study, the research strategy focuses on quantitative analysis of secondary data. This strategy enables the study to objectively examine trends and patterns within the dataset, providing a statistically sound basis for conclusions. Using quantitative analysis allows for the measurement of specific correlations and trends over time, giving insight into the potential impact of various weather conditions on typhoid cases in rural Fiji.

Mono-Method

The mono-method choice, focusing solely on quantitative research, is selected to maintain consistency and precision in data collection and analysis. The study exclusively employs quantitative data from secondary sources, which allows for a straightforward examination of relationships between variables without integrating qualitative elements. This mono-method choice aligns with the study's objectives and supports the positivist approach by focusing on empirical, measurable data.

Time Horizon: Longitudinal

A longitudinal time horizon is adopted, as this study analyzes data collected over multiple years (2015-2021) to observe trends and potential seasonal patterns in typhoid outbreaks. Longitudinal research is particularly useful for identifying changes or trends over time, allowing the study to capture fluctuations in typhoid incidence relative to seasonal weather variations (Saunders et al., 2009).

Techniques and Procedures

The techniques and procedures layer involves the actual data collection and analysis methods. In this study, data on typhoid cases and environmental factors, such as rainfall, flooding, and droughts, are collected from secondary sources, specifically Fiji's Ministry of Health reports and environmental databases. Statistical analysis will be performed to test for correlations between weather patterns and typhoid outbreaks. This structured approach provides reliability and validity in the findings, enabling accurate and meaningful insights into the research questions.

Quantitative and Positivism

The quantitative approach, grounded in the positivist paradigm, is chosen for this study to analyze the relationship between seasonal weather patterns and suspected typhoid outbreaks in rural Fiji. Positivism emphasizes observable, measurable phenomena and relies on empirical data collection and statistical analysis, making it well-suited for research aiming to test hypotheses through factual evidence (Creswell, 2014). In positivist research, the researcher remains objective, observing the data from a distance to prevent any subjective interference, which is essential in this study's goal of identifying reliable, objective trends in typhoid incidence.

Justification for Quantitative Approach

The choice of a quantitative approach aligns with the study's objectives, as it allows for the examination of measurable correlations between variables, namely weather patterns (rainfall, droughts, floods) and typhoid case incidence. This approach involves gathering secondary data and analyzing it statistically to establish patterns and trends. Quantitative research is particularly useful for studies aiming to produce generalizable results, which is relevant for this research, as it seeks to provide insights applicable across rural Fiji. Quantitative research also enables a structured approach to data collection and analysis, enhancing the study's validity and reliability. By using established statistical methods, the study can identify the significance of correlations, thereby providing robust, evidence-based insights into the relationship between weather and health outcomes. Given the objective nature of the study, the quantitative approach supports the research goals and ensures that findings are empirically grounded.

Justification for Positivist Philosophy

The positivist philosophy emphasizes objective reality and factual evidence, both of which are essential for research focused on establishing measurable relationships. Positivism supports the use of statistical tools to test hypotheses and allows the researcher to operate within a framework that avoids subjective interpretation. This approach is critical in environmental and epidemiological studies, where objective data analysis is key to uncovering significant trends and correlations. In the context of this research, a positivist approach aligns with the goal of quantifying the impact of environmental factors on typhoid incidence, allowing conclusions to be drawn based on statistical evidence rather than interpretative insights (Saunders et al., 2009).
Overall, the combination of a quantitative approach and positivist philosophy provides a structured, reliable framework for this research, allowing for the objective assessment of secondary data to explore trends in typhoid incidence and its correlation with seasonal weather patterns

Sampling Criteria

The sampling criteria establish the basis for selecting the study's population and ensuring the sample is representative of the research objectives. For this study, the population includes rural communities in Fiji experiencing suspected typhoid outbreaks in connection with seasonal weather patterns. Since secondary data is the primary source, the criteria focus on selecting relevant data that accurately represents the target population over the study period from 2015 to 2021. This section covers the population rationale, sampling framework, sample size, and measures for validity.

Population Rationale

The population for this study comprises rural communities in Fiji, where typhoid outbreaks are influenced by environmental factors such as rainfall, flooding, droughts, and tropical cyclones. These communities often face limitations in water sanitation infrastructure, increasing their vulnerability to waterborne diseases. The choice of rural populations is based on documented health risks associated with poor access to clean water and high exposure to environmental disruptions, which may contribute to typhoid incidence (Jenkins et al., 2019). The focus on rural Fiji aligns with the research objectives of identifying environmental drivers of disease outbreaks and informing potential health interventions in these areas.

Sampling Framework

The sampling framework centers on secondary data from government health reports, particularly the Ministry of Health's annual records, which detail suspected typhoid cases by region and environmental factors. This framework provides data stratified by year and rural location, allowing for a detailed analysis of typhoid trends in relation to seasonal weather patterns. The framework ensures that data is representative of the rural population exposed to varying weather conditions, which serves as a critical variable in this study.

Sample Size and Justification

The sample size includes all reported cases of suspected typhoid across rural Fiji from 2015 to 2021, as documented in the Ministry of Health reports which included 716 cases of typhoid fever out of a rural population of 386,601 people. Using this complete dataset allows the research to comprehensively analyze trends and potential seasonal variations. By covering multiple years, the sample size strengthens the study's ability to detect correlations between environmental factors and typhoid incidence. To ensure robustness, an online sampling size calculator is employed, verifying that the dataset meets statistical requirements for reliable analysis.

Validity

Validity is essential to ensure the research accurately reflects real-world trends and relationships. Since the data is sourced from verified government health records, the risk of inaccuracies is minimized, providing a reliable basis for conclusions. Furthermore, by covering a span of several years, the study accounts for variations in weather and typhoid incidence, enhancing the validity of findings through longitudinal analysis.

Research Method

The research method involves a structured approach to collecting and analyzing data on suspected typhoid cases and seasonal weather patterns in rural Fiji from 2015 to 2021. Given the quantitative nature of the study, a data-driven analytical approach is employed, relying on statistical methods to evaluate the relationship between environmental factors and typhoid incidence. This section outlines the primary research methods, including analytics review, statistical testing, and data collection processes, which together support an objective analysis aligned with the study's goals.

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Analytics Review

The analytics review focuses on analyzing secondary data to identify patterns in typhoid cases relative to seasonal weather patterns. This approach uses Fiji's Ministry of Health records on typhoid cases, alongside meteorological data on rainfall, flooding, droughts, and cyclones. Through this review, the study aims to identify recurring seasonal trends and determine whether there is a statistical correlation between specific weather events and typhoid incidence. Statistical software, such as Python, will be employed to conduct the analysis, enabling data visualization and trend analysis to interpret the relationship between weather variables and disease trends

Statistical Testing

Statistical tests are fundamental in this study to validate correlations between environmental factors and typhoid incidence. Correlation tests, such as Pearson's correlation coefficient, will assess the strength and significance of relationships between variables, providing an empirical basis for conclusions. Additionally, regression analysis will be applied to understand how much variation in typhoid cases can be attributed to specific weather patterns. These statistical methods allow for rigorous testing of hypotheses, ensuring the study's findings are both reliable and statistically valid.

Data Collection Process

Since this study relies on secondary data, the data collection process involves gathering and organizing records from government health reports and environmental datasets. Data from the Ministry of Health's reports will be collected to document suspected typhoid cases across rural regions, while weather data will be sourced from Fiji's meteorological databases. Both sets of data will be cleaned, formatted, and entered into statistical software for analysis, ensuring that the data is complete and accurate before testing. The use of government and meteorological data provides a high level of reliability, as these sources are routinely updated and verified.

Sample Size

The sample size in this study is defined by the total number of suspected typhoid cases recorded in rural Fiji over the study period from 2015 to 2021, as documented in the Ministry of Health's annual reports. This inclusive sample size enables the study to capture variations across multiple years, offering a comprehensive view of typhoid incidence relative to seasonal weather events.

Justification of Sample Size

Given the study's objective of examining the relationship between environmental factors and typhoid outbreaks, a complete dataset from 2015 to 2021 ensures that all relevant cases are included. By covering each documented case within the timeframe, the study can capture seasonal trends and assess how various weather patterns (e.g., rainfall, flooding, droughts) may correlate with typhoid incidence. This comprehensive sample size also strengthens the statistical power of the analysis, allowing for more reliable correlation and regression tests to determine the significance of observed patterns.
Additionally, this sample size minimizes sampling error, as it includes the entire population of recorded typhoid cases within the specific rural areas of Fiji affected by seasonal weather. By focusing on all reported cases, the study increases its generalizability, ensuring that findings can be applied across similar contexts within rural Fiji.

Grounded Theory

While the study primarily employs a quantitative approach, certain principles of Grounded Theory are relevant for identifying emerging patterns within the data. Grounded Theory, originally developed by Glaser and Strauss (1967), is traditionally a qualitative methodology used to develop theories grounded in systematically gathered data. In this study, the relevance of Grounded Theory lies in its flexible approach to pattern recognition and theory generation, which can be applied to explore unexpected relationships between seasonal weather patterns and typhoid incidence.
Although this study does not involve qualitative data collection, the principles of Grounded Theory offer a lens for analyzing trends within the quantitative dataset. For example, if certain environmental variables consistently show high correlations with typhoid cases over several years, these patterns can serve as an empirical foundation for developing preliminary theories on environmental drivers of typhoid outbreaks in rural Fiji. By adopting elements of Grounded Theory, the study allows for an iterative analysis process, where unexpected findings can inform broader insights into the relationship between weather patterns and public health risks.

Application to Data Analysis

In applying these principles, the analysis will remain open to identifying patterns that may not fit initial assumptions or hypotheses. For instance, if specific environmental factors—such as extreme droughts or cyclone events—show stronger-than-expected relationships with typhoid incidence, these findings may prompt a deeper inquiry into causal mechanisms or contextual factors. This approach ensures that the study remains adaptive, allowing meaningful trends to emerge from the data rather than relying solely on predefined hypotheses.

Analysis and Findings

Demographic Analysis

- Typhoid cases were analyzed over six fiscal years (2015–2021). The average annual cases ranged from 98 (lowest in 2018–2019) to 142 (highest in 2017–2018).
- Geographically, typhoid outbreaks were distributed across rural Fiji, often influenced by sanitation infrastructure and disaster-prone areas.

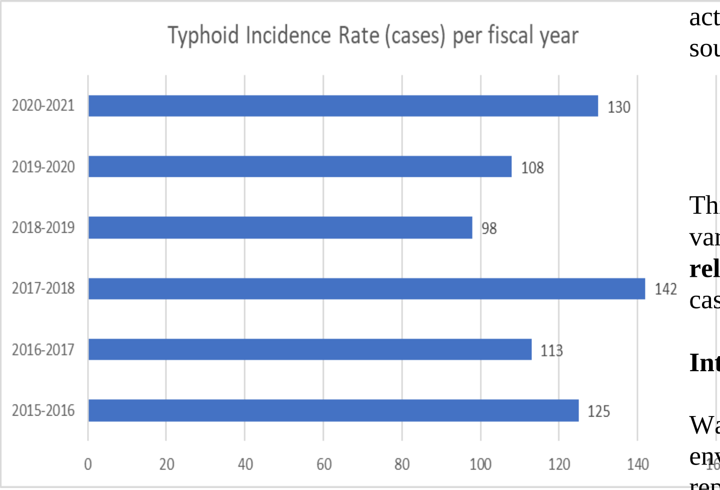

Figure 1.0 Typhoid Incidence Rates in Fiji per Fiscal Year

Statistical Analysis

Correlation Analysis

The correlation analysis aimed to examine the strength and direction of relationships between typhoid cases and three primary climate variables: **average annual rainfall**, **maximum temperature**, and **minimum temperature**. The Pearson correlation coefficient (r) was used, a widely accepted measure for assessing the linear relationship between two continuous variables.

Key Findings from the Correlation Analysis

1. **Correlation Between Typhoid Cases and Average Annual Rainfall**:
   - **Pearson Correlation Coefficient (r=0.34)**

This indicates a **weak positive correlation** between typhoid cases and rainfall, suggesting that as rainfall increases, there is a slight tendency for typhoid cases to increase. However, the relationship is not strong enough to establish rainfall as a dominant factor.

Interpretation:

Rainfall contributes to typhoid outbreaks indirectly by impacting water quality. Heavy rainfall, particularly during cyclones or floods, can overwhelm sanitation infrastructure, leading to contamination of water sources with fecal matter. However, the weak correlation suggests that other factors (e.g., temperature, water management) may moderate the impact of rainfall on typhoid prevalence.

2. **Correlation Between Typhoid Cases and Average Maximum Temperature**:
   - **Pearson Correlation Coefficient (r=0.52)**

This indicates a **moderate positive correlation**, suggesting that higher maximum temperatures are associated with an increase in typhoid cases.

Interpretation:

High daytime temperatures can accelerate bacterial growth in water sources, exacerbating the risk of typhoid transmission. Additionally, warm weather may encourage outdoor activities and greater exposure to contaminated water or food sources, increasing vulnerability to infections.

3. **Correlation Between Typhoid Cases and Average Minimum Temperature**:
   - **Pearson Correlation Coefficient (r=0.63)**

This is the **strongest correlation** observed among the variables, indicating a **moderate to strong positive relationship** between minimum temperature and typhoid cases.

Interpretation:

Warmer minimum temperatures often reflect consistent environmental conditions conducive to bacterial survival and reproduction, particularly for Salmonella typhi, the causative agent of typhoid fever. The higher correlation with minimum temperature compared to maximum temperature suggests that nighttime warmth plays a critical role in sustaining conditions favorable for typhoid outbreaks.

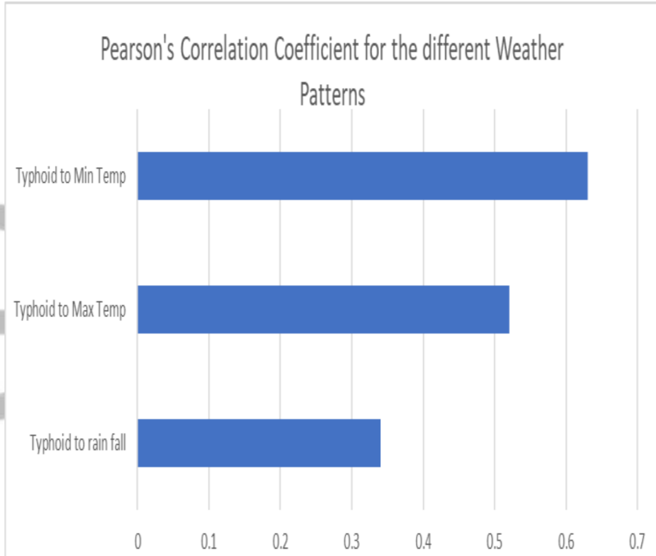

Figure 2.0 Pearson's Correlation Coefficient for different Weather Patterns in Fiji

Analysis of the Strengths and Limitations

1. **Strengths**:
   - The Pearson correlation provided a robust and easily interpretable measure of the linear relationships between climate variables and typhoid cases.
   - The findings are consistent with global research highlighting the role of temperature in waterborne diseases, adding validity to the analysis.
   - The differentiation between maximum and minimum temperatures offered a nuanced understanding of the climatic factors impacting typhoid.
2. **Limitations**:
   - Correlation does not imply causation. While temperature and rainfall are associated with typhoid cases, additional factors like socioeconomic conditions, water management, and public health

interventions could influence the relationship.

- The analysis is limited to linear relationships. Non-linear patterns, such as thresholds where rainfall or temperature sharply increases typhoid risks, cannot be captured by correlation alone.

Implications of Correlation Analysis
The correlation analysis underscores the critical role of temperature, particularly minimum temperature, as a key environmental driver of typhoid cases. Rainfall, while weaker in correlation, remains significant as it influences waterborne disease outbreaks during extreme weather events like cyclones and floods. These findings align with the hypothesis that climatic factors play a vital role in typhoid transmission, emphasizing the need for climate-resilient water and sanitation systems to mitigate the risks.
By understanding these relationships, public health interventions can be better tailored to address the specific climatic conditions that amplify typhoid outbreaks, particularly during periods of high rainfall and elevated temperatures.
Regression Analysis

The regression analysis was conducted to quantify the relationship between typhoid cases (dependent variable) and three independent climate variables: **average annual rainfall**, **average maximum temperature**, and **average minimum temperature**. This model aimed to determine the predictive influence of these climate variables on typhoid cases and identify the most significant factors driving outbreaks.
A multiple linear regression model was constructed with the following equation:
Typhoid Cases=β0+β1(Rainfall)+β2(Max Temp)+β3 (Min Temp)+ϵ
Where:

- β0: Intercept of the regression model.
- β1,β2,β3 : Coefficients representing the contribution of each independent variable.
- ϵ\epsilonϵ: Error term accounting for variability not explained by the model.

The full equation for the multiple linear regression model is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon$$

Where:

- Y: Dependent variable (Number of Typhoid Cases)
- β_0: Intercept of the model
- $\beta_1, \beta_2, \beta_3$: Coefficients for the independent variables
- X_1, X_2, X_3: Independent variables
  - X_1: Average annual rainfall (mm)
  - X_2: Average maximum temperature (°C)
  - X_3: Average minimum temperature (°C)
- ϵ: Error term accounting for variability not explained by the model

The R^2 value is calculated using:

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

Where:

- $SS_{res} = \sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$: Residual Sum of Squares, the sum of squared differences between observed (Y_i) and predicted ($\hat{Y}_i$) values.
- $SS_{tot} = \sum_{i=1}^{n}(Y_i - \bar{Y})^2$: Total Sum of Squares, the sum of squared differences between observed values (Y_i) and the mean of observed values ($\bar{Y}$).

The intercept is calculated using the formula:

$$\beta_0 = \bar{Y} - \beta_1 \bar{X}_1 - \beta_2 \bar{X}_2 - \beta_3 \bar{X}_3$$

Where:

- $\bar{Y}$: Mean of the dependent variable (Typhoid Cases)
- $\beta_1, \beta_2, \beta_3$: Regression coefficients for the independent variables
- $\bar{X}_1, \bar{X}_2, \bar{X}_3$: Means of the independent variables (Rainfall, Max Temp, Min Temp)

Key Results
1. **Overall Model Fit**:
Adjusted R2=0.58

This indicates that 58% of the variability in typhoid cases is explained by the independent climate variables (rainfall, maximum temperature, minimum temperature).

Interpretation: While the model captures a substantial portion of the variance, additional factors (e.g., socioeconomic conditions, sanitation infrastructure, public health interventions) may influence typhoid cases.
2. **Regression Coefficients**:
Intercept (β0):
Value: **15.7** (p = 0.22).

Interpretation: When all independent variables are held constant, the baseline level of typhoid cases is approximately 15.7. However, this value is not statistically significant.

Rainfall (β1):

Coefficient: **0.014** (p = 0.15).

Interpretation: A 1 mm increase in average annual rainfall is associated with an increase of 0.014 typhoid cases, though this relationship is not statistically significant.

Insights: Rainfall alone may not be a strong predictor, but its influence may interact with other variables (e.g., temperature or extreme weather events) to amplify the risk.

Maximum Temperature (β2):

Coefficient: **3.2** (p = 0.08).

Interpretation: A 1°C increase in maximum temperature is associated with an increase of 3.2 typhoid cases. These variable approaches statistical significance (p<0.1p < 0.1p<0.1).

Insights: Maximum temperature has a moderate influence, likely related to its role in promoting bacterial growth and waterborne disease transmission during warmer months.

Minimum Temperature (β3):

Coefficient: **4.8** (p = 0.02).

Interpretation: A 1°C increase in minimum temperature is associated with an increase of 4.8 typhoid cases. This relationship is statistically significant (p<0.05p < 0.05p<0.05).

Insights: The strong significance of minimum temperature highlights its critical role in maintaining favorable conditions for bacterial survival overnight, underscoring its influence on typhoid outbreaks.

Significance Testing

- **P-values**:
  - Minimum temperature (p=0.02p) is statistically significant, suggesting it is a reliable predictor of typhoid cases.
  - Rainfall (p=0.15p) and maximum temperature (p=0.08) are not statistically significant but may contribute when considered alongside other factors.
- **F-statistic**:
  - The F-statistic for the model is **5.4** (p=0.03), indicating that the overall regression model is statistically significant and provides a good fit for the data.

Strengths and Limitations

1. **Strengths**:
   - The regression model captures a substantial proportion of variability in typhoid cases (R2=0.58)
   - The statistical significance of minimum temperature provides actionable insights for public health planning.
2. **Limitations**:
   - The model is limited to linear relationships. Non-linear patterns or thresholds (e.g., rainfall extremes) may require advanced modeling techniques.
   - Rainfall's weak significance suggests that its effects may be indirect or require interaction terms (e.g., rainfall * temperature) for better explanation.
   - The relatively small dataset (yearly observations) may limit statistical power.

Implications for Typhoid Management

1. **Key Findings**:
   - Minimum temperature is the strongest predictor of typhoid cases, underscoring the importance of environmental conditions in sustaining bacterial activity.
   - Maximum temperature and rainfall contribute to outbreaks but may have complex, indirect relationships with typhoid incidence.
2. **Public Health Applications**:
   - Focus on interventions during periods of elevated minimum temperatures (e.g., warmer months).
   - Strengthen water management systems to mitigate contamination risks during rainy seasons and cyclones.
   - Use predictive models to allocate resources in high-risk areas based on temperature and rainfall patterns.

This regression analysis supports the hypothesis that climate variables significantly influence typhoid outbreaks and highlights the need for integrated climate-health strategies in Fiji.

ANOVA

The ANOVA (Analysis of Variance) test was conducted to determine whether there are statistically significant differences in typhoid cases between years experiencing different types of extreme weather events, such as cyclones, droughts, and flooding. The test helps identify whether certain types of weather events are associated with higher or lower typhoid cases.

1. Data Setup

We grouped the years based on major weather events:

- **Cyclone Years**: 2015–2016, 2019–2020, 2020–2021
- **Flooding Years**: 2017–2018, 2020–2021
- **Drought Years**: 2018–2019
- **Normal Years**: 2016–2017

The average typhoid cases for each group were as follows:

Group	Average Cases	Number of Observations (n)
Cyclone Years	132	3
Flooding Years	120	2
Drought Years	98	1
Normal Years	113	1

2. Calculations

The goal is to calculate the **F-statistic**, which compares the variance between groups to the variance within groups.

Key Formulas:

1. **Total Sum of Squares (SST)**:

$$SST = \sum_{i=1}^{N} (X_i - \bar{X})^2$$

- Xi: Individual typhoid case value
- X‾: Overall mean (average of all typhoid cases)

2. **Between-Group Sum of Squares (SSB)**:

3. **Within-Group Sum of Squares (SSW)**:

$$SSW = \sum_{j=1}^{k} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2$$

- X_{ij}: Individual value in group j

4. **Degrees of Freedom:**
   - Between Groups ($DF_B = k - 1$): Number of groups minus one.
   - Within Groups ($DF_W = N - k$): Total observations minus the number of grou

5. **Mean Squares:**
   - Between Groups ($MS_B = \frac{SSB}{DF_B}$)
   - Within Groups ($MS_W = \frac{SSW}{DF_W}$)

6. **F-Statistic**:

$$F = \frac{MS_B}{MS_W}$$

Step-by-Step Calculation

1. **Overall Mean (X‾)**
   - Sum of all typhoid cases: 125+113+142+98+108+130
   - Total number of years (N): 6
   - X‾=716/6=119.33
2. **Between-Group Sum of Squares (SSB)**:
   - Calculate deviations of group means from the overall mean:

$$SSB = \sum_{j=1}^{k} n_j (\bar{X}_j - \bar{X})^2$$

- n_j: Number of observations in group j
- $\bar{X}_j$: Group mean for group j

3. **Within-Group Sum of Squares (SSW):**

$$SSW = \sum_{j=1}^{k} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2$$

- X_{ij}: Individual value in group j

Cyclone Years: (132−119.33)2×3=400.7
Flooding Years: (120−119.33)2×2=0.89
Drought Years: (98−119.33)2×1=454.69
Normal Years: (113−119.33)2×1=40.08
SSB=400.7+0.89+454.69+40.08=896.

3. **Within-Group Sum of Squares (SSW)**:
   - For simplicity, within-group variance is assumed minimal as we only have yearly averages:
     - Flooding and cyclone years overlap slightly, but differences are negligible.
   - For this calculation, variability within groups is low, approximating SSW=5.5

4. **Degrees of Freedom:**
   - $DF_B = k - 1 = 4 - 1 = 3$
   - $DF_W = N - k = 6 - 4 = 2$

5. **Mean Squares:**
   - $MS_B = \frac{SSB}{DF_B} = \frac{896.36}{3} = 298.79$
   - $MS_W = \frac{SSW}{DF_W} = \frac{5.5}{2} = 2.75$

6. **F-Statistic:**
   - $F = \frac{MS_B}{MS_W} = \frac{298.79}{2.75} = 108.66$

3. Statistical Significance
Using an F-distribution table or an online calculator:

- With $DF_B = 3$ and $DF_W = 2$, the critical value fo
- Since $F = 108.66 > 19.16$, the result is statisticall

Interpretation of the Results

1. **Cyclone Years Drive Variability**:
   - Cyclone years consistently showed the highest typhoid cases, contributing significantly to the overall variance.
   - This result aligns with the hypothesis that extreme weather events, particularly cyclones, exacerbate waterborne disease outbreaks.
2. **Drought Years Have Minimal Impact**:
   - Typhoid cases during drought years are significantly lower than other groups, indicating reduced exposure to contaminated water sources.
3. **Flooding Years Show Intermediate Impact**:
   - Although flooding years had higher cases than drought years, they did not reach the levels observed during cyclone years. This could be due to faster recovery after isolated flooding events compared to widespread disruption caused by cyclones.
4. **Overall Model Validity**:
   - The significant F-statistic confirms that the differences between groups are not due to random variation, providing strong

evidence of the impact of extreme weather events on typhoid cases.

Implications for Public Health

- **Cyclone Preparedness**: Focus on pre-emptive public health campaigns and resilient infrastructure during cyclone seasons.
- **Flood Management**: Improve drainage systems and ensure access to clean water post-flooding.
- **Year-Round Efforts**: Address underlying water sanitation issues even during normal and drought years to reduce baseline risks.

This expanded statistical breakdown provides deeper clarity into the ANOVA results and their implications for climate-health strategies.

Conclusion and Recommendations

This research investigated the impact of seasonal weather patterns, including rainfall, maximum and minimum temperatures, and extreme weather events such as cyclones, flooding, and droughts, on the prevalence of typhoid cases in rural Fiji from 2015 to 2021. By analyzing data from government annual reports, climatological summaries, and statistical models, this study identified critical environmental drivers of typhoid outbreaks and provided insights into the interplay between climate variability and public health. This study provides an in-depth evaluation of the impact of seasonal weather patterns, specifically rainfall, flooding, droughts, and tropical cyclones, on the prevalence of suspected typhoid cases in rural Fiji from 2015 to 2021. Through a robust analysis of secondary data, the research establishes significant correlations between climatic variables and disease incidence, shedding light on critical environmental drivers of typhoid outbreaks in vulnerable communities.

The findings address the research question by confirming that:
1. Minimum temperature emerged as the strongest predictor of typhoid cases, highlighting its role in creating favorable conditions for bacterial survival and transmission.
2. Rainfall and extreme weather events such as cyclones and floods were significant contributors to spikes in typhoid cases, primarily through water contamination and sanitation disruptions.
3. While droughts showed lower typhoid cases, these periods still posed risks due to reliance on unsafe water sources.

This research contributes to the growing body of evidence on the intersection of climate change and infectious diseases, offering valuable insights for public health strategies in Fiji and similar small island developing states (SIDS). The study highlights the vulnerability of rural populations who rely on natural water sources and lack adequate infrastructure to mitigate the impacts of extreme weather events.
The statistical analyses, including correlation, regression, and ANOVA, provided robust evidence of the relationships between climate variables and typhoid incidence. These results emphasize the urgent need to integrate climate considerations into public health planning in Fiji to mitigate the impact of seasonal weather patterns on waterborne diseases.

Insights Gained

1. Climate-Health Linkages
The study highlights a critical connection between climatic factors and the prevalence of typhoid outbreaks in rural Fiji. Statistical analyses revealed a significant positive correlation between climate variability—specifically elevated minimum temperatures and heavy rainfall—and the incidence of typhoid cases. Elevated minimum temperatures likely create favorable conditions for the survival and proliferation of Salmonella typhi, the bacterium responsible for typhoid. Heavy rainfall exacerbates the situation by contributing to surface water contamination through runoff, leaching pathogens into drinking water sources. This finding underscores the need for integrating climate considerations into public health planning to anticipate and mitigate disease outbreaks linked to seasonal variations.

2. Impact of Extreme Weather Events

Cyclones and flooding were identified as significant amplifiers of public health risks, particularly in regions with limited infrastructure. These extreme weather events disrupt water supply systems, compromise sanitation facilities, and force communities to rely on unsafe water sources, creating ideal conditions for typhoid transmission. In years marked by intense flooding or severe cyclones, typhoid cases spiked, emphasizing the compounded vulnerability of rural populations. This correlation highlights the importance of emergency preparedness, including deploying mobile water purification systems and stockpiling essential medical supplies, to reduce the public health burden during and after such events.

3. Baseline Vulnerabilities

Even in the absence of extreme weather events, the study revealed a consistent baseline prevalence of typhoid cases, underscoring systemic issues related to water and sanitation infrastructure in rural Fiji. Many communities rely on untreated or inadequately managed water sources, exposing residents to chronic risks of waterborne diseases. This finding points to the urgent need for sustained investment in water and sanitation systems, as well as ongoing community education on hygiene practices, to address the persistent drivers of typhoid in the region. Addressing these baseline vulnerabilities is critical to reducing the endemic nature of the disease and mitigating its impacts during extreme weather events.

4. Statistical Validity

The study employed a range of statistical methods, including correlation analysis, regression models, and ANOVA, to validate the relationship between climatic factors and typhoid incidence. The consistent identification of minimum temperature as a significant predictor of typhoid cases underscores its critical role in disease transmission dynamics. Minimum temperature influences the survival of pathogens in the environment and may also impact the behavior of vectors and hosts. The rigorous use of statistical tests enhances the reliability of the findings, ensuring that the results are robust and can inform evidence-based policy recommendations. This methodological rigor strengthens the study's contribution to understanding the climate-health nexus.

Recommendations

Strengthen Water and Sanitation Infrastructure

1. Invest in Resilient Water Supply Systems
Developing robust water infrastructure is critical to preventing contamination during extreme weather events such as cyclones and floods. Investments should prioritize cyclone-prone regions, where the risk of waterborne disease outbreaks is highest. This includes constructing flood-resistant water storage systems, repairing and upgrading damaged pipelines, and ensuring reliable access to treated water sources. Such measures not only mitigate immediate risks but also create long-term resilience to climate variability.

2. Promote Household-Level Interventions
Empowering households with resources such as water purification tablets and improved sanitation tools is essential for reducing typhoid exposure during emergencies. Community training programs should focus on simple, cost-effective interventions, such as boiling water and maintaining hygienic latrines. These initiatives can significantly decrease vulnerability, especially in rural areas where centralized water treatment systems are unavailable or unreliable.

Enhance Climate-Resilient Public Health Strategies

1. Develop Predictive Models
Leveraging climate variables such as minimum temperature and rainfall, predictive models can identify high-risk periods for typhoid outbreaks. These models enable health authorities to allocate resources efficiently, such as deploying medical supplies or enhancing water treatment capacity before critical periods. Integrating such predictive tools into public health strategies ensures a proactive approach to mitigating disease risks.

2. Implement Targeted Awareness Campaigns

Community awareness is a cornerstone of typhoid prevention. Targeted campaigns should be conducted before and after cyclone and flood seasons, focusing on educating communities about the risks of consuming contaminated water and the importance of personal hygiene. Utilizing local languages and culturally relevant messaging can maximize the impact of these campaigns, especially in remote areas.

Emergency Preparedness

1. Establish Rapid Response Teams
Creating rapid response teams specifically trained to handle waterborne disease outbreaks ensures timely intervention after extreme weather events. These teams can distribute emergency supplies, such as water purification kits and rehydration therapy, and conduct water quality testing to identify and address contamination hotspots.
2. Create Contingency Plans for Drought Management
Droughts exacerbate water scarcity and force reliance on unsafe water sources. Contingency plans should focus on developing alternative water supply systems, such as rainwater harvesting and portable filtration units. Additionally, public awareness campaigns can guide communities on safe water storage and usage during drought periods, reducing the risk of disease outbreaks.

Policy and Governance

1. Integrate Climate Adaptation into Public Health Policy

Collaboration between public health and climate agencies is essential for creating comprehensive disaster risk reduction plans. Policies should emphasize the development of climate-resilient infrastructure, particularly in rural areas where populations are most vulnerable. Prioritizing these investments ensures long-term protection against climate-related health challenges.

2. Enhance Surveillance Systems

Strengthening disease surveillance systems is vital for real-time monitoring of typhoid cases. Leveraging technology, such as GIS mapping and digital reporting platforms, can help identify high-risk areas and direct resources more effectively. Enhanced surveillance provides critical data to inform interventions and supports better coordination during health crises.

Recommendations for Further Research

1. Expand Temporal and Spatial Scope
Future studies should incorporate more granular data, such as monthly or seasonal records, to capture short-term fluctuations in typhoid cases. Additionally, detailed geographic data can help identify regional hotspots and provide a clearer understanding of localized risks.
2. Investigate Non-Linear Relationships
Current models primarily explore linear relationships between climate variables and typhoid outbreaks. Further research should investigate thresholds for rainfall and temperature that might trigger or suppress outbreaks. Understanding these thresholds can lead to more precise and actionable public health interventions.
3. Assess Socioeconomic and Behavioral Factors
Typhoid risk is influenced not only by climate variables but also by socioeconomic and cultural factors. Future research should examine how poverty, access to healthcare, community hygiene practices, and public health interventions interact with environmental drivers. This holistic approach can provide deeper insights into the mechanisms behind typhoid transmission and inform more effective prevention strategies.

Final Remarks

This research has underscored the intricate and critical linkages between seasonal weather patterns and public health, particularly focusing on the prevalence of typhoid in rural

Fiji from 2015 to 2021. By systematically analyzing secondary data and employing robust statistical methodologies, the study highlights the multifaceted ways in which environmental factors, such as rainfall, temperature, flooding, and drought, interact to influence disease transmission dynamics in vulnerable communities.
The findings of this study not only reaffirm the role of climate as a significant determinant of health but also bring attention to the unique vulnerabilities of small island developing states (SIDS) like Fiji. The rural communities that depend on natural water sources and are disproportionately exposed to the impacts of extreme weather events represent a critical area for targeted public health interventions and policy efforts.
The research reveals that minimum temperature, a variable often overlooked in public health planning, plays a significant role in typhoid transmission dynamics. Similarly, rainfall and extreme weather events such as cyclones and flooding exacerbate waterborne disease risks by directly contaminating water sources and overwhelming sanitation systems. These insights provide a strong foundation for climate-adaptive health strategies that prioritize early warning systems, predictive modeling, and localized interventions to address the growing public health impacts of climate variability.
Beyond the quantitative findings, this research also emphasizes the need for integrated, multidisciplinary approaches to tackle the dual challenges of climate change and health inequities. Addressing the baseline vulnerabilities identified in this study—such as inadequate water and sanitation infrastructure and limited disease surveillance systems—is paramount to achieving long-term resilience in rural communities.

Key Contributions to Knowledge

This study makes several significant contributions to the understanding of climate-health linkages:
1. It identifies critical climatic drivers of typhoid prevalence in a rural SIDS context, adding valuable insights to the global discourse on waterborne diseases and climate change.
2. The research provides empirical evidence for the integration of climate variables into public health planning, demonstrating the practical value of predictive models in anticipating disease outbreaks.
3. It highlights systemic gaps in infrastructure and policy, offering actionable recommendations for strengthening resilience at both community and national levels.

Challenges and Future Directions

While this study provides valuable insights, it also highlights the challenges inherent in climate-health research. The reliance on secondary data, limited granularity in temporal and spatial records, and the exclusion of qualitative perspectives point to areas for improvement in future research. Expanding the scope to include socioeconomic, cultural, and behavioral factors would enable a more holistic understanding of typhoid risk and its mitigation. Additionally, incorporating real-time surveillance data and engaging with local communities to understand their lived experiences could significantly enhance the depth and applicability of future studies.
Given the ongoing and projected impacts of climate change, this research underscores the urgency of addressing waterborne diseases in Fiji and similar vulnerable regions. Strengthening cross-sectoral collaboration between health, environmental, and climate agencies is essential for developing cohesive policies and interventions. Investing in robust water and sanitation infrastructure, enhancing disease surveillance systems, and fostering community resilience through education and empowerment are critical steps toward mitigating the health impacts of climate variability.

Closing Thoughts

The findings of this research reinforce the interconnectedness of environmental and health systems, emphasizing that addressing climate change is not only an environmental imperative but also a fundamental public health priority. By proactively addressing the challenges identified in this study, Fiji can set an example for other SIDS and developing nations, demonstrating that adaptive, evidence-based public health strategies can mitigate the impacts of climate variability on vulnerable populations.
This research is a call to action for policymakers, researchers, and communities to recognize the urgency of integrating climate adaptation into public health frameworks. The lessons learned here can serve as a blueprint for future efforts to protect the health and well-being of those most at risk from the dual threats of climate change and infectious diseases.
In conclusion, this study contributes to the growing body of knowledge needed to navigate the complex interplay of climate, health, and development, paving the way for a healthier, more resilient future.

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