East African Journal of Health and Science, Volume 8, Issue 2, 2025
Article DOI: https://doi.org/10.37284/eajhs.8.2.3492

East African Journal of Health and Science
eajhs.eanso.org
Volume 8 Issue 2, 2025
Print ISSN: 2707-3912 | Online ISSN: 2707-3920
Title DOI: https://doi.org/10.37284/2707-3920

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

An Analysis of Geospatial Patterns and Diarrhoeal Prevalence in Children Under Five: A Case Study of Matungulu and Mavoko Sub-Counties, Kenya

Winfred Mbinya Manetu[1*] *Kennedy Nyabuti Ondimu*[2] *& Amon Mwangi Karanja*[3]

[1] Tharaka University, Marimanti, Kenya.
[2] Egerton University, Nakuru, Kenya.
[3] Masinde Muliro University of Science and Technology, Kakamega, Kenya.
*Author for Correspondence ORCID ID; https://orcid.org/0000-0002-4627-5347; Email: bnyaw2015@gmail.com

Article DOI: https://doi.org/10.37284/eajhs.8.2.3492

Date Published:

14 August 2025

Keywords:

Childhood Diarrhoea, Prevalence, Hotspots Analysis, Spatial Distribution.

ABSTRACT

Despite ongoing advancements in prevention efforts, diarrhoea remains a critical public health challenge, particularly threatening the health of infants and young children. The rising prevalence of childhood diarrhoea, especially in developing nations, has emerged as a pressing concern within public health discourse. This study examined both the prevalence and spatial distribution of diarrhoea-related illness among children under the age of five, with the goal of enhancing the monitoring and implementation of effective intervention programs. Data were collected from 398 mothers or caregivers of children under five years through a structured survey. The prevalence rate was determined by dividing the number of reported diarrhoea cases by the total number of children in the sampled households. To analyse spatial distribution patterns, the study employed spatial statistical techniques, including Moran's I and Getis-Ord Gi*. Findings indicated a high two-week prevalence rate of childhood diarrhoea, affecting 34% of children under five in Mavoko and Matungulu Sub-Counties. Mavoko reported a higher rate at 37%, compared to 27% in Matungulu. Hotspot analysis using Moran's I and Getis-Ord Gi* identified the western parts of Mavoko, specifically Athi River, Mlolongo, and sections of Katani and Kinanie, as areas with significantly high diarrhoea prevalence. These spatial insights highlight the need for geographically targeted interventions. The study recommends prioritising high-prevalence hotspots through improved access to safe water, expansion of sewerage systems, enhanced waste management, and strengthened hygiene promotion programs. Such targeted measures, combined with sustained surveillance and community engagement, could significantly reduce disease burden and improve child health outcomes within and beyond the study area.

APA CITATION

Manetu, W. M., Ondimu, K. N. & Karanja, A. M. (2025). An Analysis of Geospatial Patterns and Diarrhoeal Prevalence in Children Under Five: A Case Study of Matungulu and Mavoko Sub-Counties, Kenya. *East African Journal of Health and Science*, *8*(2), 249-260. https://doi.org/10.37284/eajhs.8.2.3492

CHICAGO CITATION

Manetu, Winfred Mbinya, Kennedy Nyabuti Ondimu and Amon Mwangi Karanja. 2025. "An Analysis of Geospatial Patterns and Diarrhoeal Prevalence in Children Under Five: A Case Study of Matungulu and Mavoko Sub-Counties, Kenya". *East African Journal of Health and Science* 8 (2), 249-260. https://doi.org/10.37284/eajhs.8.2.3492

Article DOI: https://doi.org/10.37284/eajhs.8.2.3492

HARVARD CITATION
Manetu, W. M., Ondimu, K. N. & Karanja, A. M. (2025). "An Analysis of Geospatial Patterns and Diarrhoeal Prevalence in Children Under Five: A Case Study of Matungulu and Mavoko Sub-Counties, Kenya", *East African Journal of Health and Science*, 8(2), pp. 249-260. doi: 10.37284/eajhs.8.2.3492

IEEE CITATION
W. M., Manetu, K. N., Ondimu & A. M., Karanja "An Analysis of Geospatial Patterns and Diarrhoeal Prevalence in Children Under Five: A Case Study of Matungulu and Mavoko Sub-Counties, Kenya", *EAJHS*, vol. 8, no. 2, pp. 249-260, Aug. 2025.

MLA CITATION
Manetu, Winfred Mbinya, Kennedy Nyabuti Ondimu & Amon Mwangi Karanja. "An Analysis of Geospatial Patterns and Diarrhoeal Prevalence in Children Under Five: A Case Study of Matungulu and Mavoko Sub-Counties, Kenya". *East African Journal of Health and Science*, Vol. 8, no. 2, Aug. 2025, pp. 249-260, doi:10.37284/eajhs.8.2.3492.

INTRODUCTION

Acute respiratory infections and diarrhoea are among the leading causes of childhood mortality worldwide (Liu et al., 2015; Troeger et al., 2018). Globally, diarrhoea affects approximately 1.7 billion children annually and is the second leading cause of mortality among children under five (Ho et al., 2019). Each year, over 525,000 children worldwide lose their lives due to diarrhoeal diseases (*WHO 2017*, n.d.).Nevertheless, diarrhoea cases are predominantly found in low-income countries, where limited resources and weaker urban and healthcare infrastructure present significant challenges compared to high-income nations(Almasi et al., 2022a). Nearly 90% of global diarrheal deaths among children and a substantial portion of the overall disease burden are concentrated in countries within sub-Saharan Africa and South Asia (Naghavi et al., 2017). Research indicates that diarrheal diseases disproportionately impact areas with limited access to healthcare, clean water, sanitation, and low-income or marginalised nations (Troeger et al., 2017).

For example, in Kenya, a low-income country, diarrheal disease poses a significant public health challenge and ranks among the top ten causes of mortality and morbidity in children under five (Manetu et al., 2021). Similarly, other African nations, such as Ethiopia and Somalia, continue to face the burden of childhood diarrhoea (Asfaha et al., 2018; Ayele et al., 2014; Kabew et al., 2019). Further studies conducted in Uganda, Rwanda, and Malawi reported diarrhoea prevalence rates of 32%, 26.7%, and 20%, respectively (Tareke et al., 2022). Diarrheal disease in children has become a crucial health concern in Kenya. Despite various interventions and strategies aimed at control, the mortality rate from diarrhoea among children under five remains alarming. In order to identify areas and populations that are at high risk of diarrheal outbreaks, studies on spatial distribution patterns of diarrhoea within geographical areas and populations are essential (Dmello et al., 2022). A better understanding of such spatial distribution patterns could aid in identifying high-risk areas and help take preventive measures during the early stages of diarrhoea outbreaks and spread (Ghosh et al., 2021).

The Kenya Demographic Health Survey (KDHS) 2022 reveals that diarrhoea remains a leading cause of illness and death among young children in Kenya (*KDHS, 2022*. According to the report, the national prevalence of under-five diarrhoeal diseases stands at 14% despite ongoing interventions; the burden of diarrhoeal disease remains substantial, with significant variation in prevalence and contributing factors across different regions of the country. Therefore, this study was undertaken to investigate the prevalence and spatial variation of diarrhoea among children in Mavoko and Matungulu sub-counties. Among the various analytical methods for studying spatial disease patterns and identifying significant clustering within a specific geographical area (Ghosh et al., 2023; Hernández-Vásquez et al., 2023; Almasi et al., 2022b). We employed Moran's I spatial autocorrelation method. This approach effectively detects spatial patterns by accounting for both the locations of incidents and the associated disease cases.

Study's Specific Objectives

This study aims to;

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- To determine the two-week prevalence of diarrhoea among children under five years in Mavoko and Matungulu sub-counties.
- To examine the spatial distribution and clustering of cases using Moran's I and Getis-Ord Gi*.
- To map geographical hotspots and cold spots to guide targeted public health interventions.

Research Questions

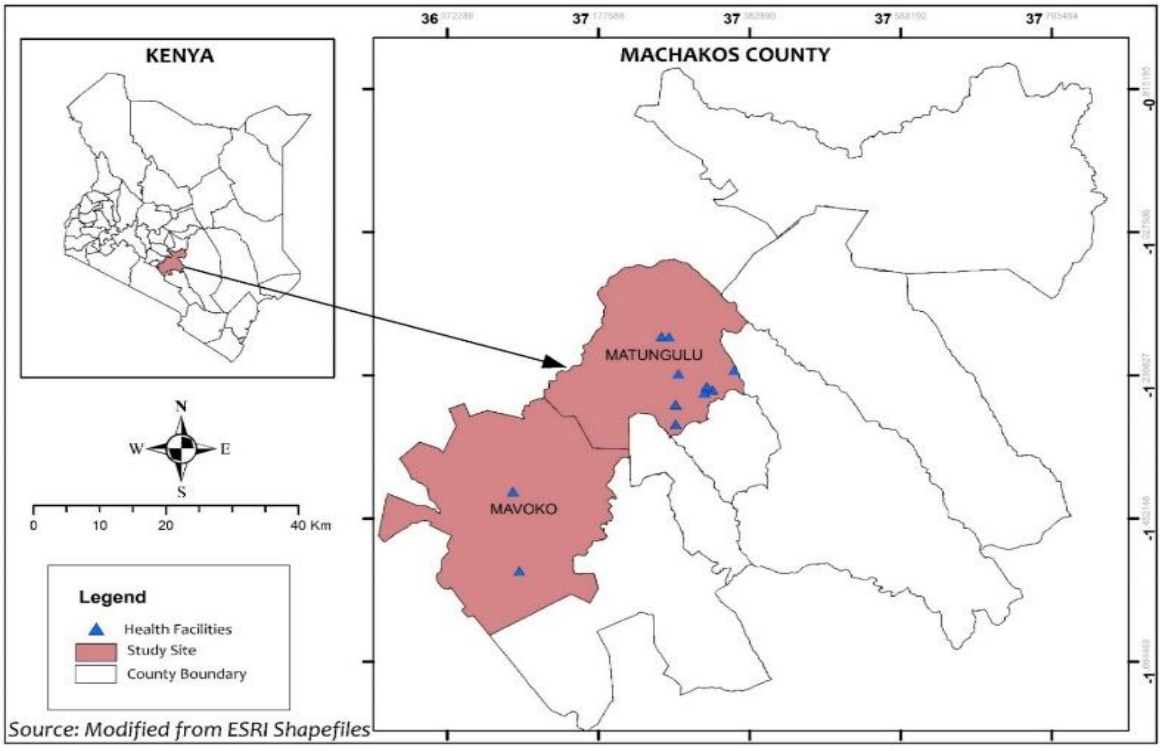
- What is the two-week prevalence of diarrhoea among children under five in Mavoko and Matungulu sub-counties?
- How is diarrhoea spatially distributed within the study area, and are there significant clusters or hotspots?
- Which geographical locations should be prioritised for targeted diarrhoea prevention and control efforts?

MATERIALS AND METHODS

Study Area and Description

The study was carried out in Mavoko and Matungulu sub-counties in Machakos County, Kenya, focusing on children under five who had experienced diarrhoea within the two weeks preceding the survey. Mavoko Sub-County spans approximately 852 square kilometres and has a population of 322,499, resulting in a population density of around 378 people per square kilometre. In comparison, Matungulu Sub-County has a population of 161,557, with a density of about 277.9 people per square kilometre. These sub-counties differ in their levels of access to healthcare services, sanitation, and clean water, factors that significantly impact the occurrence of diarrhoeal diseases. Machakos County has an infant mortality rate of approximately 34 deaths per 1,000 live births and an under-five mortality rate of 41 deaths per 1,000 live births, highlighting persistent challenges in child health and disease prevention. Mavoko Sub-County is made up of seven locations: Gutunguri, Katani, Mlolongo, Kinanie, Lukenya, Athi River, and Mavoko. Meanwhile, Matungulu Sub-County comprises ten locations: Kalandini, Matuu, Kiboko, Kyanzavi, Kyeleni, Komorok, Matheini, Matungulu, Nguluni, and Tala.

Figure 1: Study Locational Area and Extend



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Data on diarrhoea episodes among children under five were collected from 398 households. Diarrhoea was defined following WHO and UNICEF (2007) as the passage of three or more loose or watery stools within a 24-hour period. The sample size was determined using Yamane's (1967) formula with a 5% margin of error, ensuring an optimal balance between statistical precision and logistical feasibility. Using census-derived household population data, this calculation yielded a target of 398 households, which were selected through random sampling across all administrative locations to ensure representativeness. Of the surveyed households, 97 did not have children under five, leaving 301 eligible households. These contained a total of 400 children under five, 114 in Matungulu and 286 in Mavoko, forming the basis for prevalence calculations. Spatial data were gathered by recording the geographic coordinates of each household using the Kobo Collect App, enabling detailed spatial analysis through Moran's I, Getis-Ord Gi*, and ordinary kriging to assess distribution patterns and identify hotspots.

Data Analysis

Childhood Diarrhoea Prevalence Rate

To determine the prevalence rate of childhood diarrhoea among the 398 surveyed households, the number of reported diarrhoea cases was divided by the total number of children under five in these households, and the result was multiplied by 100 to express it as a percentage. This provided the diarrhoea prevalence rate for the surveyed population. The overall prevalence rate for Machakos County was then calculated using the standard prevalence formula, based on aggregated data from all surveyed households across the county. Beyond the county-level analysis, the study also performed a more localised assessment by examining diarrhoea prevalence at the location level within both Mavoko and Matungulu sub-counties. This finer-scale analysis aimed to detect geographic variations in prevalence, allowing for the identification of specific areas with higher rates or potential diarrhoea hotspots.

Spatial Autocorrelation Analysis

The spatial distribution of diarrhoea cases in Machakos County was analysed using Moran's I and Getis-Ord Gi* techniques. Moran's I measured spatial autocorrelation to determine whether diarrhoea rates were clustered, dispersed, or randomly distributed, while Getis-Ord Gi* identified specific local hotspots requiring targeted intervention. To enhance precision, ordinary kriging was applied to interpolate prevalence at unsampled locations using spatial relationships and variogram modelling. The resulting maps provided clear visualisations of high-risk areas, enabling policymakers to prioritise interventions, allocate resources efficiently, and implement targeted public health measures for better diarrhoea control.

Software

All statistical and spatial analyses were conducted using QGIS (version 3.20) for mapping and spatial statistics and SPSS (version 26) for general statistical analysis. This multi-software approach ensured methodological transparency, accuracy, and robustness in both spatial and statistical analyses.

Ethical Considerations

Research ethics were upheld throughout the study. Informed consent was obtained after clearly explaining the study's purpose, procedures, risks, and benefits in an understandable format. A research permit from the National Commission for Science, Technology and Innovation was secured prior to commencement, ensuring participant rights and welfare were protected.

RESULTS

Prevalence of Childhood Diarrhoea in Mavoko and Matungulu Sub-counties

The overall prevalence of childhood diarrhoea in the study area was found to be 34%, meaning that for every 100 children under the age of five, thirty-four had experienced diarrhoea in the two weeks preceding the survey. This figure is considerably higher than both the Machakos County average of 13% and the national average

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of 14%, as reported by the Machakos Demographic and Health Survey (2019) and the Kenya Demographic and Health Survey (2022).

Table 1: Overall Prevalence of Childhood Diarrhoea in Machakos County

Diarrhoea	Prevalence rate (%)
NO	66
YES	34

Prevalence varied notably between sub-counties, as shown in Table 2. In Mavoko Sub-County, 37% of children under five had diarrhoea within the recall period, compared to 27% in Matungulu Sub-County. The disparity suggests that children in Mavoko were at a higher risk of diarrhoeal episodes than their rural counterparts in Matungulu. Within sub-counties, there were further variations by location. In Mavoko, the highest prevalence was recorded in Mlolongo (48%), followed by Athi River, while Lukenya (5%) and Syokimau/Katani (4%) reported the lowest rates. In Matungulu, Kiboko recorded the highest prevalence (19%), followed by Tala and Matuu, whereas Kyanzavi had the lowest prevalence at just 3%.

Table 3: Diarrhoea Prevalence in Locations of Mavoko and Matungulu Sub-Counties

Sub-county	Locations	NO, (%)	YES, (%)	p-value[2]
Mavoko	Athi-River	21	15	<0.001
	Githunguri	11	9	
	Kenanie	9	9	
	Kyumbi	7	10	
	Lukenya	8	5	
	Mlolongo	36	48	
	Syokimau/Katani	8	4	
		NO (%)	**YES (%)**	**p-value[2]**
Matungulu	Kalandini	6	6	0.3
	Kiboko	7	19	
	Komarock	19	10	
	Kyanzavi	7	3	
	Kyeleni	10	7	
	Matheini	6	10	
	Matungulu	5	9	
	Matuu	5	13	
	Nguluni	11	10	
	Tala	24	13	

Spatial Patterns of Childhood Diarrhoea

The Spatial Autocorrelation report presented in Figure 2 presents the spatial distribution of childhood diarrhoea cases using Moran's Index. The results indicated a slight tendency towards clustering, with a positive Moran's Index of 0.06, suggesting that geographically proximate areas exhibit similar rates of diarrhoea occurrence. The analysis yielded a z-score of 2.15, which fell within the significant range, indicating that the observed pattern was unlikely to be due to random chance. Additionally, the p-value of 0.03 further supported this finding, as it was below the 0.05 threshold for statistical significance. These findings imply that certain areas had significantly different rates of diarrhoea, potentially due to varying factors. Identifying and understanding these clusters is crucial for effective public health planning and intervention, as it allows for targeted measures to address the underlying causes of higher incidence rates in specific areas. The study's positive spatial autocorrelation (Moran's Index of 0.06) indicates a tendency for similar

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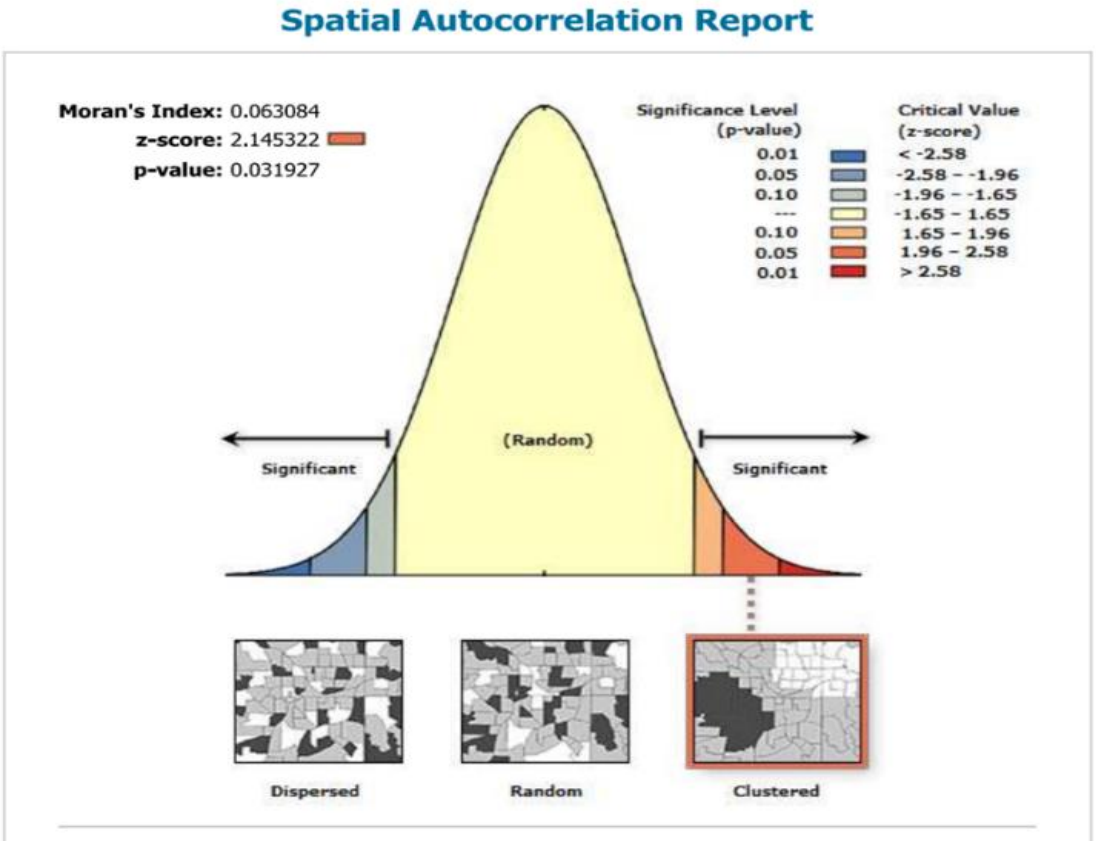
values to cluster together, reflecting a certain level of spatial pattern in the data.

Figure 2: Global Moran's I value of childhood diarrhoea disease in Machakos County.



Hot-spot Analysis

The hotspot analysis map (Figure 3) of childhood diarrhoeal cases, represented by Gi Z-Scores, indicated significant spatial variability within the study area. The western part of the region, which covers areas across Mlolongo and Athi River of the Mavoko Sub County and parts of Kinanei, showed several high-intensity hotspots marked by dark orange to red points with Z-scores between 0.9467 and 2.171, suggesting a critical need for intervention in these areas. The central region had moderate hotspots, which include the intermediate parts of Mavoko Sub-county and Matungulu Sub-county, indicated by yellow to light orange points with Z-scores between -0.6130 and 0.9466. The northern and eastern parts, which largely cover the locations of Matungulu Sub-county, displayed lower case intensities, shown by blue and grey points with Z-scores between -1.908 and -0.613. This spatial analysis highlights the need for targeted public health measures, prioritising high-incidence areas in the western region while maintaining efforts in the central and eastern regions to prevent potential outbreaks.

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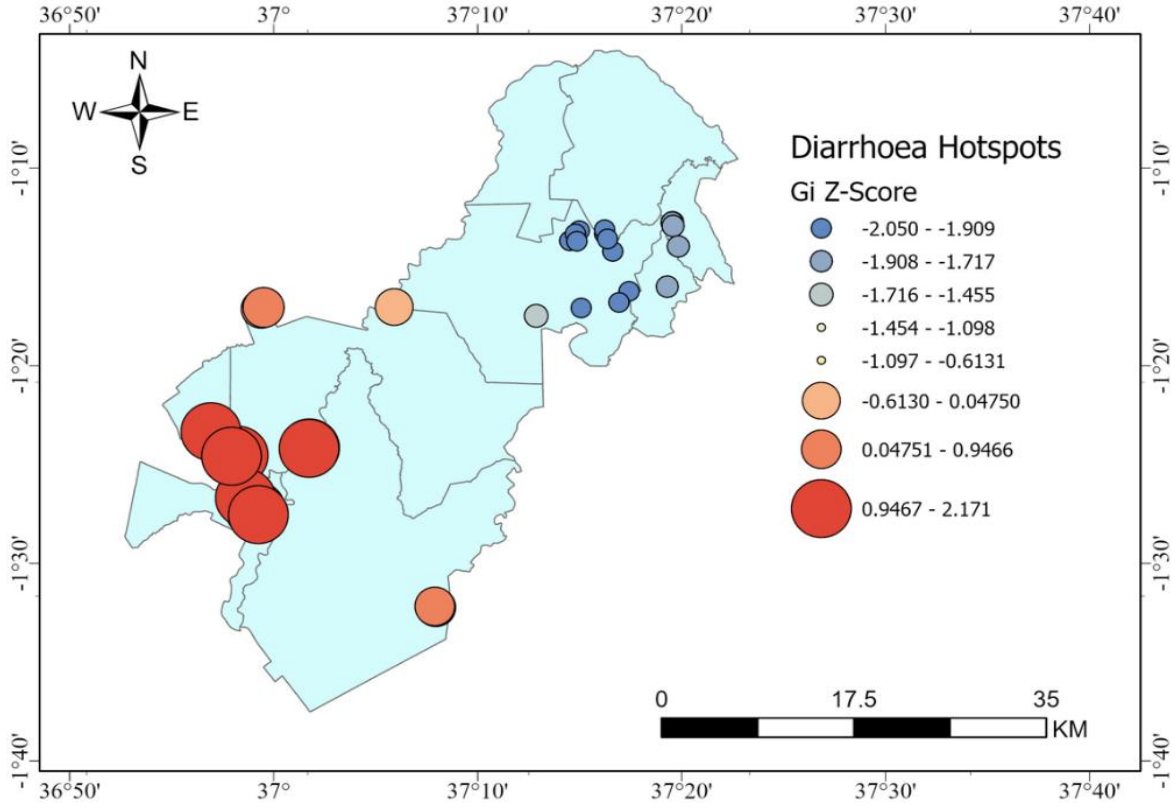
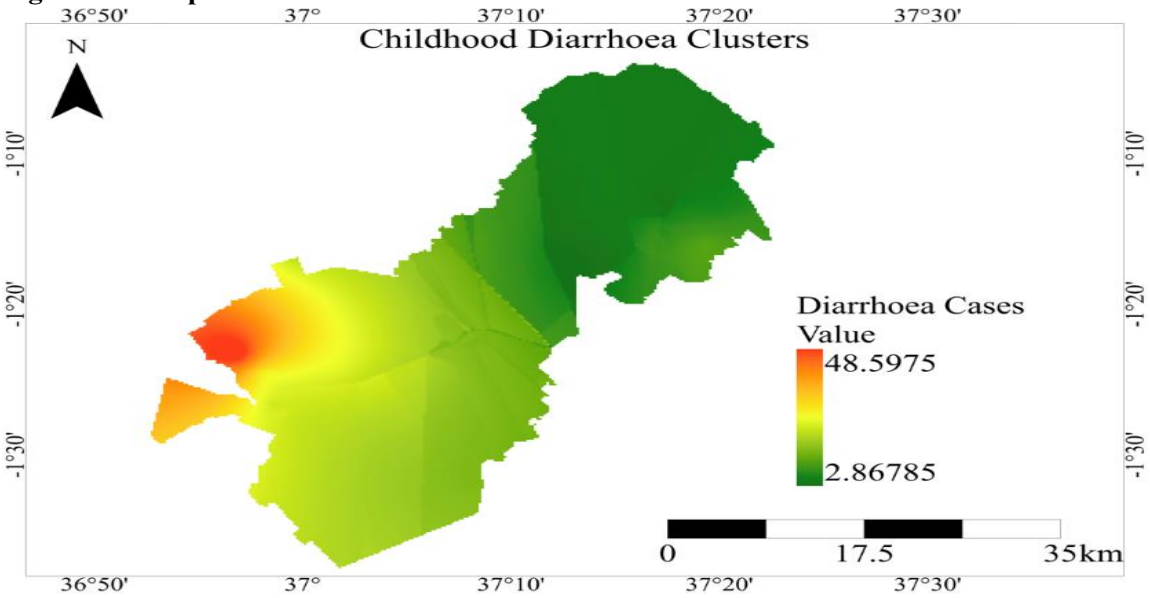
Figure 3: Local Moran's I cluster map for childhood diarrhoea in Machakos County



The interpolation of point clusters in Figure 4 using ordinary kriging provided a powerful tool for visualising the geographical distribution of childhood diarrhoea across the study area. By creating a continuous surface, this method allowed for a detailed and nuanced understanding of how diarrhoea incidence varied spatially, highlighting regions with both elevated and reduced rates of infection. This visualisation was crucial for identifying potential hotspots, areas where the incidence of diarrhoea was significantly higher, which could inform targeted public health interventions and resource allocation. Ordinary kriging was particularly advantageous for this analysis due to its foundation in spatial statistical methods. As the best linear unbiased estimator, ordinary kriging excelled in making predictions based on limited data, which was especially valuable in public health studies where the available datasets could be sparse or unevenly distributed. This method not only provided accurate interpolation but also offered insights into the spatial relationships inherent in the data. Another significant advantage of ordinary kriging was its ability to account for spatial clustering and screening.

Article DOI: https://doi.org/10.37284/eajhs.8.2.3492

Figure 4: Interpolated Clusters of Childhood Diarrhoea



DISCUSSION

The study findings indicate that childhood diarrhoea remains a significant public health burden in the study area, with a prevalence rate of 34% more than double the county and national averages. This elevated rate points to persistent environmental and infrastructural challenges that undermine child health despite ongoing health interventions. The higher prevalence in Mavoko compared to Matungulu reflects the so-called "urban health penalty," where rapid urbanisation, high population density, inadequate waste management, intermittent water supply, and exposure to industrial pollutants combine to create a higher disease burden. This pattern aligns with global observations by the World Health Organization (2021) and parallels studies from Dhaka, Bangladesh (Khan et al., 2014) and India (Sarkar & Webster, 2017), which also reported higher diarrhoeal incidence in urban and peri-urban settings. Location-specific differences were also evident. In Mlolongo and Kiboko, higher prevalence rates may be linked to overcrowding, shared sanitation facilities, and contamination of water sources. In contrast, cold spots such as Kyanzavi and Lukenya are likely benefiting from lower population densities, better waste disposal practices, and more reliable access to clean water.

The observed spatial clustering of diarrhoea cases, confirmed by the positive Moran's I value, supports the idea that environmental and socio-economic conditions shared within certain geographic areas strongly influence disease risk. Similar clustering phenomena have been documented in Ethiopia (Bogale et al., 2017) and India (Dmello et al., 2022). The high-intensity hotspots identified in Athi River, Mlolongo, Katani, and Kinanie are urban areas characterised by high population density, which often leads to overcrowding and strains on water and sanitation infrastructure. Rapid urbanisation in these regions may result in inadequate access to clean water and proper waste disposal practices, increasing the risk of water contamination and the spread of diarrhoeal diseases. Additionally, the presence of industrial activities and environmental pollutants further exacerbates the issue by contributing to unsafe water sources. This finding is consistent with studies conducted in semi-urban areas of north-eastern Ethiopia and a peri-urban settlement of Lusaka, Zambia (Natnael et al., 2021; Nyambe et al., 2020), which found the prevalence of acute diarrhoea to be high in semi-urban areas.

Similarly, in rural regions such as Kalandini, Kyanzavi, Kyeleni, Komarock, Nguluni, and Matungulu, which were identified as cold spot locations in Matungulu Sub-County (Figure 4.2 & Figure 4.3), the incidence of diarrhoea was relatively low compared to other areas within the sub-county. The lower incidence in these

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locations is attributed to several factors, including lower population density, which reduces the likelihood of disease transmission due to less crowded living conditions. Furthermore, these regions are more rural and less industrialised, resulting in fewer environmental contaminants that could pollute water sources. In our study, we also found that children resident in rural settings reported lower odds of diarrhoea compared to children in urban settings. This was consistent with the findings of Apanga and Kumbeni (2021) in Ghana. However, our finding was inconsistent with a recent systematic review in Ethiopia (Alebel et al., 2018).

The observed patterns may be explained by the urban health penalty theory, which posits that urban areas tend to concentrate poor people and expose residents to unhealthy environments, leading to a disproportionate burden of poor health (Freudenberg et al., 2005). This could possibly account for the higher prevalence of diarrhoea in children resident in urban areas compared to rural areas.

CONCLUSION

This study found that diarrhoea remains a significant public health concern among children under five in Machakos County, with an overall prevalence of 34%. The burden was not uniformly distributed: Mavoko Sub-County, particularly its urban areas, recorded markedly higher rates, emerging as diarrhoea hotspots. In contrast, Matungulu Sub-County, predominantly rural, showed lower prevalence and was identified as a cold spot. These spatial disparities point to underlying differences in socio-demographic characteristics, environmental conditions, and behavioural practices influencing diarrhoea occurrence.

The elevated prevalence in Mavoko suggests persistent challenges related to access to safe drinking water, adequate sanitation, and hygiene practices, compounded by higher population density. Meanwhile, the lower prevalence in Matungulu underscores the potential benefits of rural environmental conditions but also signals the need for sustained preventive measures to avoid future increases. The results highlight the importance of location-specific strategies to address the root causes of diarrhoeal disease and to strengthen child health outcomes across both urban and rural settings.

Recommendations

To address the burden of childhood diarrhoea and support long-term disease prevention, the study recommends reducing childhood diarrhoea in Machakos County by expanding clean water supply, improving sanitation infrastructure in urban hotspots, and ensuring proper drainage to prevent contamination. Alongside these measures, sustained hygiene education focusing on safe water storage, handwashing with soap, and proper waste disposal should be promoted in communities and schools to instil lasting healthy habits and reduce disease prevalence.

Acknowledgement

I extend my sincere gratitude to the primary caregivers for their time and openness in sharing crucial information on their children's health, which was vital to understanding childhood diarrhoea in Machakos County. I also thank the data collectors for their dedication and professionalism in ensuring accurate data under challenging conditions.

Conflict of Interest Declaration

The author declares no conflict of interest.

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