Journal of Nursing Research, Patient Safety and Practice
Vol: 03, No. 02, July-Dec 2023
ISSN: 2799-1210, DOI: 10.55529/jnrpsp.35.39.52

Research Paper

Geospatial evaluation of service areas: empowering maternal health for ensuring healthy lives and well-being in the Wenchi Municipality of Ghana

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Article Info

Article History:
Received: 05 July 2023
Revised: 16 September 2023
Accepted: 22 September2023
Published: 07 November 2023

Keywords:
Sustainable Development
Maternal Healthcare
Public Health
Well-Being
GIS
Service Area

ABSTRACT

Background: Accessibility to maternal health services is an important determinant of maternal health outcomes, especially in lower resource settings where distances can pose a significant challenge to prompt access to health care. The aim of the study was to assess the geospatial distribution of maternal healthcare service areas in Wenchi Municipality, Ghana and to pinpoint areas of inaccessibility.
Methods: Service areas were mapped around nine health facilities using Geographic Information System (GIS) mapping, network analysis and Thiessen polygons. Accessibility analysis was conducted in 85 communities and a vulnerability map was created to show local inequalities in access to maternal health services.
Results: This analysis showed a linear catchment pattern surrounding health facilities, showing that there were significant areas where there were gaps in accessing maternal healthcare services. Of the 85 communities studied, only 34 (34%) had access to maternal health services, and most communities had to deal with different levels of access issues.
Conclusion: The result of this study shows that there are huge gaps in maternal healthcare accessibility in Wenchi Municipality with the majority of the communities being underserved. It is recommended that there is improvement of accessibility through targeted infrastructure development, community engagement programs and technology integration.

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Journal of Nursing Research, Patient Safety and Practice (JNRPSP)

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1. INTRODUCTION

Nestled within the contours of Ghana, the Wenchi Municipality grapples with the intricate tapestry of maternal health challenges that are woven into its communities. In this pursuit of sustainable well-being, a geospatial evaluation emerges as a beacon of insight, offering a unique perspective on the intersection between geography and healthcare accessibility. The contours of the land and the distribution of healthcare services are not arbitrary; they define the boundaries within which maternal health thrives or falters. As we embark on this geospatial exploration, the goal is clear: to empower maternal health initiatives and forge a resilient foundation that ensures the prosperity of both mothers and their newborns.

In the symphony of development, the Wenchi Municipality serves as a crucial score, with its melody echoing the urgency of prioritizing maternal health. By delving into the geospatial intricacies of service areas, we unveil the silent narratives of communities that may find themselves on the periphery of healthcare access. This evaluation becomes a compass guiding us through the topography of challenges, charting a course towards sustainable solutions that address the specific needs of mothers in every corner of Wenchi. In doing so, we aspire not only to bridge gaps but to build bridges—connecting communities to the vital maternal health services that lay the foundation for a healthier and more prosperous future.

As we navigate the geospatial landscape of Wenchi, our mission extends beyond mere cartography. It is a commitment to empowerment, a pledge to transform data points into meaningful interventions that uplift the health and well-being of the municipality's mothers. This geospatial evaluation isn't just a study; it is a call to action, an invitation for collaboration and innovation in the realm of maternal health. Together, armed with insights derived from the intersection of geography and healthcare, we embark on a journey toward a Wenchi Municipality where maternal well-being is not just a goal but a lived reality for every woman and child.

Did a cross-sectional study in Ghana that utilized geospatial methods to model travel times to healthcare facilities based on reported and modelled distances by 2210 women from the 2017 Maternal Health Survey. Their findings revealed that women facing reported distance challenges had significantly longer travel times, with poverty increasing the odds of such challenges. Their study highlighted disparities, indicating that poor, rural women registered with health insurance often faced longer travel times, emphasizing the need to address geographic barriers for this demographic. While the modelled travel times offered valuable insights, their study also underscored the importance of recognizing and addressing the unique challenges faced by marginalized populations in accessing maternal healthcare using GIS. also did a cross-sectional study in the Upper West Region of Ghana that investigated the impact of assigning midwives to Community-Based Health Planning and Services (CHPS) on maternal health outcomes. Their study systematically selected communities based on facility proximity and interviewed 534 women who recently gave birth.

Their findings revealed that communities with midwife-assigned CHPS demonstrated significantly lower catastrophic payments for normal deliveries, suggesting the effectiveness of this local approach in improving healthcare access. However, limitations may include potential biases in community selection and the cross-sectional nature of the study. [1] Also did a study to examine the progress of Gulf Cooperation Council (GCC) states in achieving the well-being of women under Sustainable Development Goal 3 (SDG 3), focusing on maternal mortality rates (SDG 3.1) and access to sexual and reproductive health care (SDG 3.7). Utilizing a narrative review approach, his study analyzed reports from 2017 and 2018 published by the Ministries of Development and Planning of each GCC state, along with WHO reports. The findings from his study revealed a significant reduction in maternal mortality rates, with strategies such as awareness campaigns and healthcare system improvements, but highlight gaps in addressing challenges and linking SDGs with specific targets, emphasizing a cultural framing disparity in prioritizing issues. Together, these

studies underscore the complex interplay of geographic, socio-economic, and cultural factors in maternal healthcare. Integrating GIS, as seen in Dotse-Gborgbortsi's work, enhances the precision of interventions, offering a comprehensive understanding of the spatial dimensions of healthcare access. The collective insights call for holistic and context-specific strategies to ensure the well-being of women in diverse global settings.

This study uses geospatial methods to delineate and analyse the service areas of health facilities that provide maternal healthcare within the Wenchi Municipality of Ghana. The objective is to identify and map vulnerable areas with limited access to maternal healthcare, providing a targeted understanding of geographic disparities. By assessing service areas, this study informs strategic interventions that address specific needs in order to empower maternal health and contribute to the overall well-being of communities in Wenchi.

2. METHODOLOGY

2.1 Study Area

Wenchi Municipality, situated in the Bono Region of Ghana as shown in Figure 1, serves as a compelling study area due to its unique blend of cultural richness, geographical diversity, and healthcare challenges [2]. Wenchi boasts a diverse topography, encompassing fertile plains, rolling hills, and the meandering Black Volta River. This geographical diversity presents both opportunities and challenges for maternal healthcare accessibility, as communities nestled in remote areas may face difficulties in reaching healthcare facilities. Rich in history and tradition, Wenchi is home to various ethnic groups, each contributing to the vibrant cultural tapestry of the municipality. Cultural practices and beliefs play a pivotal role in shaping maternal health behaviours and decisions, influencing aspects such as birthing practices and healthcare-seeking behaviour. Despite efforts to improve healthcare infrastructure, Wenchi faces disparities in healthcare facility distribution, particularly in rural pockets. Understanding the spatial distribution of health facilities within the municipality is critical for assessing the accessibility of maternal healthcare services. Wenchi's socio-economic landscape is characterized by a mix of urban and rural communities. Factors such as poverty and educational disparities may influence maternal health vulnerability, necessitating a nuanced approach to address the diverse needs of the population.

Wenchi Municipality operates within the broader context of national and regional health policies. Studying Wenchi allows for an examination of the implementation and effectiveness of maternal health policies at the local level, offering insights into the challenges and successes faced by policymakers and healthcare providers. The municipality's communities are tightly-knit, fostering a sense of community identity and support. This interconnectedness can influence health-seeking behaviour and community-based interventions, making it essential to consider the role of social networks in maternal health outcomes. Wenchi's study area status is further justified by the need to address the challenges faced by vulnerable populations, particularly in remote and underserved areas. Simultaneously, the study presents an opportunity to identify and leverage existing community strengths and resources for the improvement of maternal health services [2].

2.2 Materials Used

In conducting the geospatial evaluation of service areas in Wenchi Municipality, a robust set of materials and tools as shown in Table 1 were employed. The study harnessed the power of ArcGIS 10.4 software, a leading geographic information system platform, to conduct intricate spatial analyses and model travel times. Administrative boundaries, road networks, forest reserves, streams, rivers, and town data provided foundational georeferenced information crucial for the comprehensive mapping of the landscape of Wenchi municipality. The spatial data on health facilities in Ghana, served as a critical component in delineating service areas and assessing healthcare accessibility, ensuring the spatial analyses of the study were anchored in accurate and up-to-date information. Collectively, these materials formed a robust toolkit, combining GIS software and diverse geospatial datasets, to illuminate the dynamics of maternal healthcare access within Wenchi Municipality.

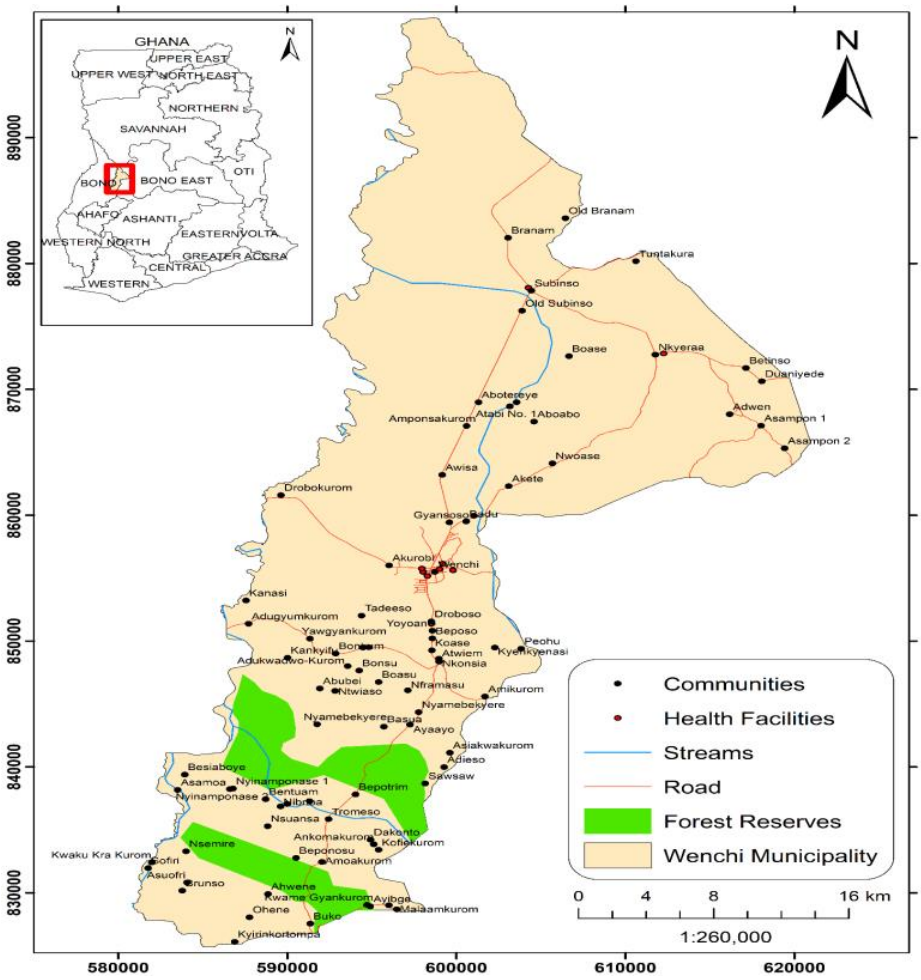


Figure 1. A Map of Wenchi Municipality in Ghana

Table 1. Materials Used with their Sources

Material	Source
ArcGIS 10.4 software	https://www.qgis.org/en/site/forusers/download.html
Administrative boundaries, roads, forest reserves, streams, rivers and towns	https://www.igismap.com/download-free-shapefile-maps/
Spatial data on health facilities in Ghana	https://data.humdata.org/dataset/hotosm_gha_health_facilities?
Global Human Settlement (GHS) population grid multitemporal	http://data.europa.eu/89h/2ff68a52-5b5b-4a22-8f40-c41da8332cfe

2.3 GIS Mapping and Analysis

In the GIS mapping and analysis phase of the study, advanced Geographic Information System (GIS) software was employed to visually depict the spatial distribution of health facilities across Wenchi Municipality. This comprehensive mapping integrated essential layers such as road networks and streams, facilitating a nuanced understanding of the geographical landscape and potential obstacles affecting travel times to healthcare facilities. Utilizing GIS capabilities, clustering algorithms were implemented to identify concentrated areas of vulnerable populations [3]. This approach allowed us to discern patterns based on socio-economic factors and demographic characteristics, shedding light on regions where maternal healthcare accessibility may be particularly challenging. By synergizing GIS technology with clustering

algorithms, this method not only visualized the distribution of health resources but also pinpointed areas demanding targeted interventions to enhance maternal health outcomes within the municipality [4].

2.4 Service Area Delineation

In the service area delineation phase, network analysis tools were harnessed to precisely determine the reach of health facilities in Wenchi Municipality. Factoring in travel times and accessibility considerations, the service areas surrounding each health facility were systematically outlined, providing a comprehensive spatial understanding of their influence [5]. This method was useful in differentiating service areas based on established travel time thresholds, effectively categorizing regions into those with optimal access to maternal healthcare services and those facing suboptimal accessibility. The utilization of network analysis tools ensured a dynamic and data-driven approach, allowing for a fine-grained assessment of maternal healthcare service coverage within the municipality. Through this method, areas requiring targeted interventions were pinpointed to optimize the allocation of resources for the enhancement of maternal health outcomes.

The service area delineation process involving travel time thresholds can be represented mathematically using Eq. (1).

$$Service\ Area = \{x \in Geographic\ Space: Travel\ Time(x) \leq Threshold\} \quad (1)$$

In this equation:

- Service Area denotes the geographical region covered by the service area of a health facility.
- x represents individual locations within the geographic space.
- Travel Time(x) signifies the calculated travel time from location x to the respective health facility.
- Threshold is the predetermined travel time threshold that distinguishes areas with optimal and suboptimal access to maternal healthcare services [5].

In this study, time was used as the cost field to delineate the service area analysis using a travel speed of 50kph and time of 38min as shown in Figure 4.

By applying this equation, the delineation of service areas becomes a systematic process, allowing for the precise identification of regions meeting the defined accessibility criteria for maternal healthcare services within Wenchi Municipality.

2.5 Identifying Communities and Populations at Risk

The integration of demographic data constitutes a pivotal methodological step, enhancing the depth of the analysis in this study of maternal healthcare accessibility in Wenchi Municipality. Through the overlay of demographic data onto GIS maps, the vulnerable populations residing in areas marked by restricted access to maternal health services were discerned. systematically analysing socio-economic and demographic factors (population density) within these mapped regions, the nuanced determinants of vulnerability were uncovered by overlaying the service areas that were generated on the population density distribution in Wenchi municipality. This approach facilitated a comprehensive understanding of the diverse characteristics influencing maternal healthcare accessibility, allowing for the tailored development of interventions to address specific community needs. The integration of demographic insights into GIS mapping not only provided a spatial context for vulnerability but also laid the groundwork for targeted and effective strategies to enhance maternal health outcomes in Wenchi.

The method employed to identify communities and populations at risk involved a multifaceted approach integrating geospatial analysis, demographic data, and community engagement. Geographic Information System (GIS) mapping was utilized to visualize the spatial distribution of healthcare facilities, road networks, and demographic indicators within Wenchi Municipality. Overlaying this information facilitated the identification of communities situated in remote or underserved areas while incorporating socio-economic data aided in pinpointing vulnerable populations. Additionally, community engagement strategies, including surveys and interviews, were implemented to gather qualitative insights into the specific challenges faced by residents. This comprehensive methodology ensured a nuanced understanding of the geographical and socio-economic factors contributing to maternal healthcare vulnerability, enabling the development of targeted interventions to address the unique needs of at-risk communities in Wenchi.

2.6 Using Thiessen Polygons with the Service Areas

In the process of identifying communities and populations at risk, Thiessen Polygons emerged as a valuable methodological tool [4]. Thiessen Polygons, also known as Voronoi Polygons, was employed through Geographic Information System (GIS) analysis to delineate service areas based on the service areas delineated from the network analysis around healthcare facilities. This technique partitions the study area into polygons where each point within a given polygon is closer to the designated healthcare facility than any other facility. By integrating demographic data within these polygons, a spatially explicit representation of community catchment areas was gained. Thiessen Polygons allowed for a more nuanced understanding of localized healthcare accessibility, helping to identify communities situated in regions with limited access. Overlaying socio-economic indicators onto these polygons facilitated the identification of populations at risk, considering factors such as poverty and educational levels [6].

This method not only provided a spatially precise identification of vulnerable communities but also offered a systematic approach to target interventions based on the unique characteristics of each population within Wenchi Municipality. the Thiessen Polygon method involves creating polygons around each healthcare facility's location, and the equation for calculating these polygons (Voronoi polygons) is as follows:

Given n healthcare facilities with coordinates (x_i, y_i) for i = 1, 2, ..., n, the Thiessen Polygon (Ti) for each facility i is determined by the set of points (x, y) that are closer to facility i than any other facility. The equation for each polygon can be expressed as shown in Eq. (2).

$$Ti = \{(x,y): \sqrt{(x-xi)^2 + (y-yi)^2} \leq (x-xj)^2 + (y-yj)^2 \text{ for all } j \neq i\} \quad (2)$$

In this equation:

- (x, y) represents a point within the Thiessen Polygon.
- (xi, yi) are the coordinates of healthcare facility i.
- The equation compares the distance from point (x, y) to facility i against the distance to all other facilities, ensuring the point is closer to facility i than any other facility.

By applying this equation to each healthcare facility in Wenchi Municipality, Thiessen Polygons are created, defining the catchment areas around each facility and aiding in the identification of communities and populations at risk based on their spatial proximity to healthcare services as shown in Figure 5 [4]. The conceptual framework of this study is shown in Figure 2.

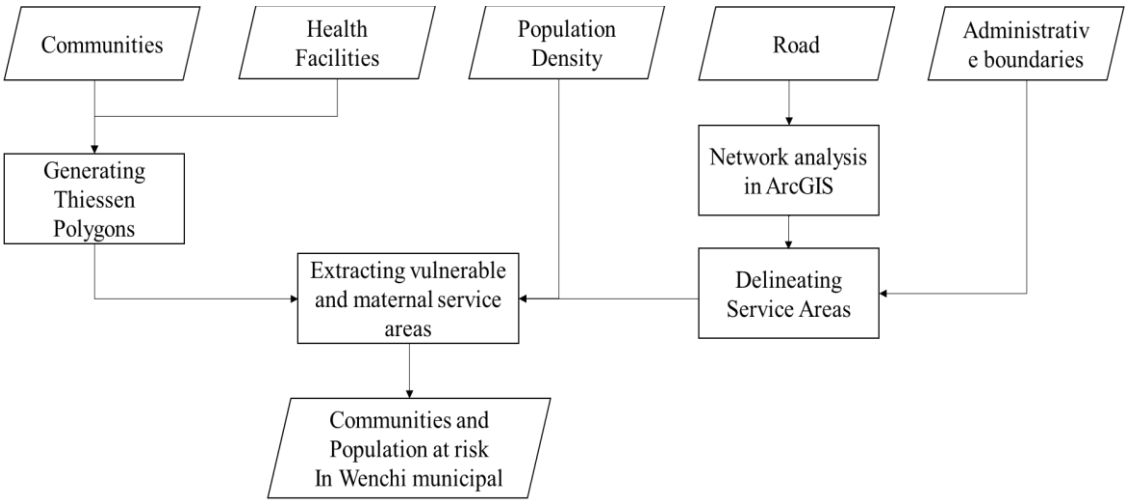


Figure 2. Conceptual Framework of the Study

3. RESULTS AND DISCUSSION

3.1 Service Areas in Wenchi Municipal

Nine (9) health facilities within the municipality revealed a linear catchment as shown in Figure 4 after network analysis in ArcGIS as shown in Figure 3.

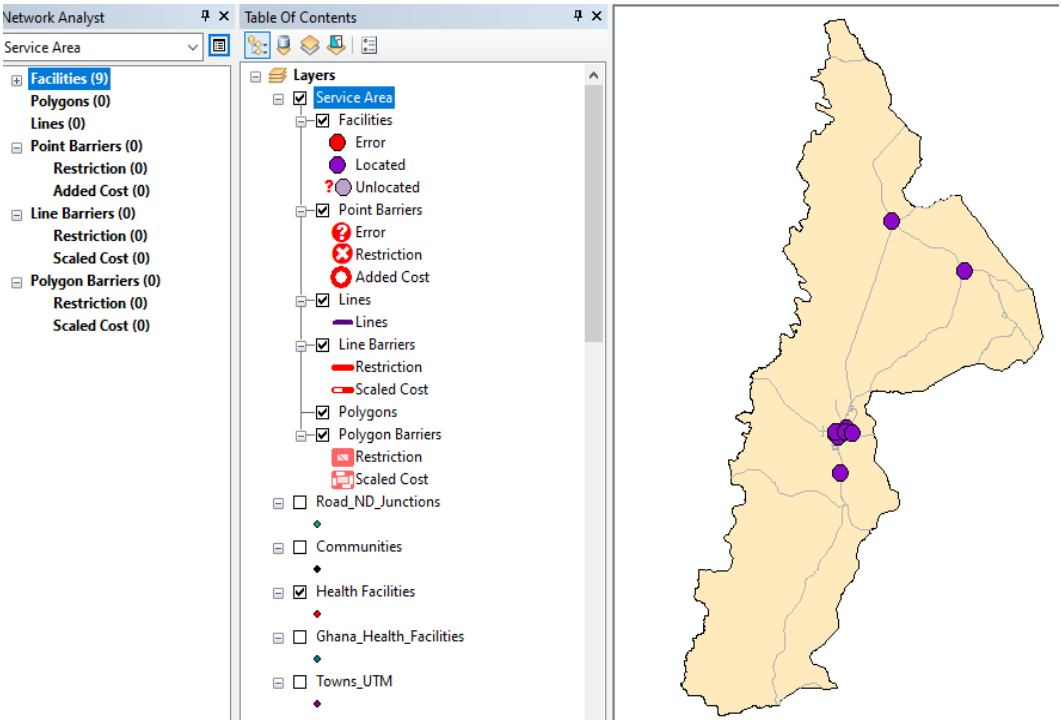


Figure 3. Loading the Spatial Location of Health Facilities into the Network Analyst Tool

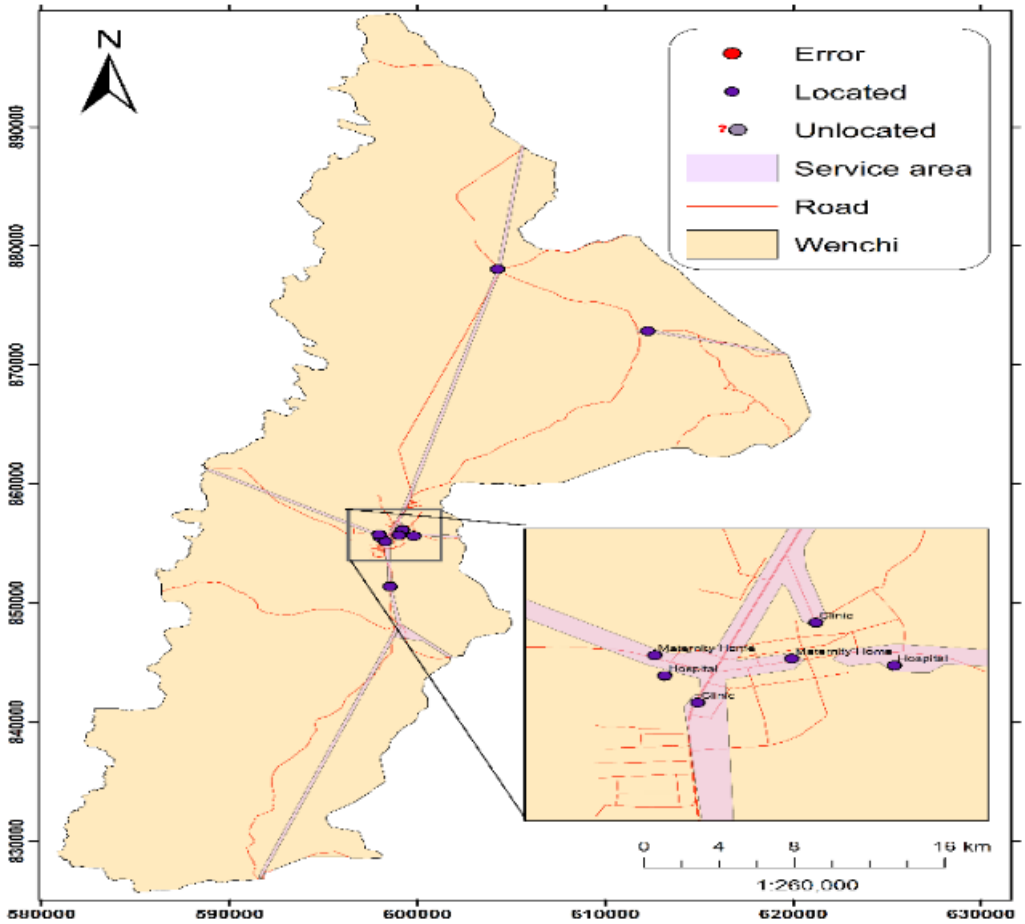


Figure 4. Delineated Service Area Using Network Analyst Tool in ArcGIS

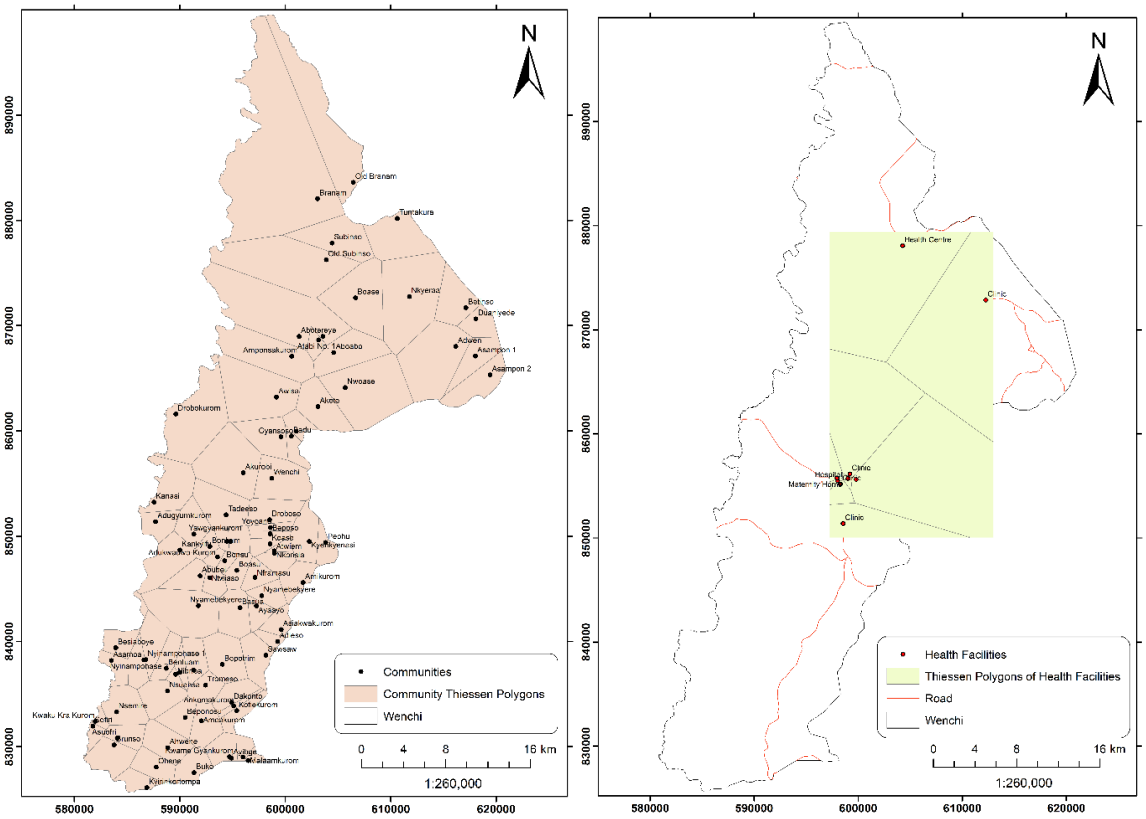


Figure 5. Thiessen Polygons of Communities (Left) and Health Facilities (Right) in Wenchi Municipality

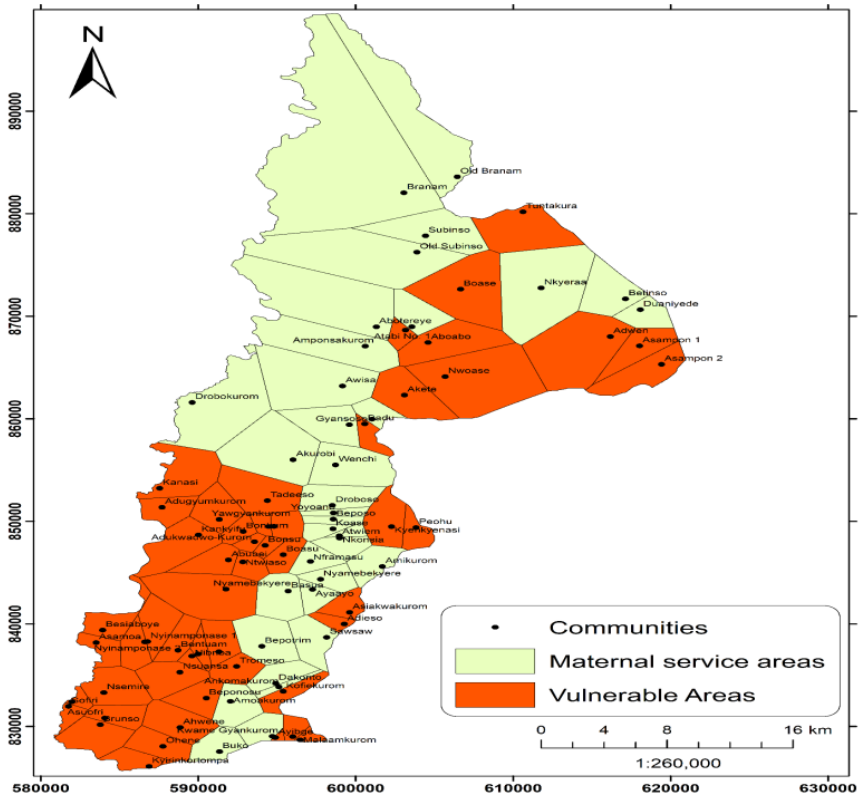


Figure 6. Vulnerability of Maternal Healthcare in the Wenchi Municipality

From Figure 6, only 34 out of 85 communities have access to maternal healthcare in the Wenchi municipality while 51 do not as shown in Table 2 and Table 3.

3.2 Population and Communities at Risk

Table 2. Vulnerable (Do Not Have Easy Access to Maternal Healthcare) Communities in Wenchi Municipality

Vulnerable Communities	
Kyirinkortompa	Bonsu
Ohene	Adukwadwo-Kurom
Malaamkurom	Kankyifu
Ayibge	Bonkum
Kwadwonsowaakurom	Peohu
Ahwene	Kyenkyenasi
Brunso	Nkyirensua
Asuofri	Degyedegye
Sofiri	Yawgyankurom
Kwaku Kra Kurom	Adugyumkurom
Beponosu	Tadeeso
Nsemire	Kanasi
Kofiekurom	Badu
Nsuansa	Akete
Tromeso	Nwoase
Nibriba	Asampon 2
Frimpon Kura	Asampon 1
Agyei Yaw Kura	Aboabo
Bentuam	Adwen
Asamoa	Atabi No. 1
Nyinamponase 2	Boase
Nyinamponase 1	Tuntakura
Besiaboye	Ntwiaso
Adieso	Abubei
Asiakwakurom	Boasu
Nyamebekyere	

Table 3. Maternal Service (Have Easy Access to Maternal Healthcare) Communities in Wenchi Municipality

Maternal Service Communities	
Buko	Yoyoano
Kwame Gyankurom	Droboso
Amoakurom	Wenchi
Ankomakurom	Akurobi
Dakonto	Gyansoso
Bepotrim	Wurompo
Sawsaw	Drobokurom
Basua	Awisa
Ayaayo	Amponsakurom
Nyamebekyere	Atabi No. 2
Amikurom	Abotereye
Nframasu	Duaniyede
Nkonsia	Betinso
Atwiem	Nkyeraa

Koase	Old Subinso
Beposo	Subinso
Old Branam	Branam

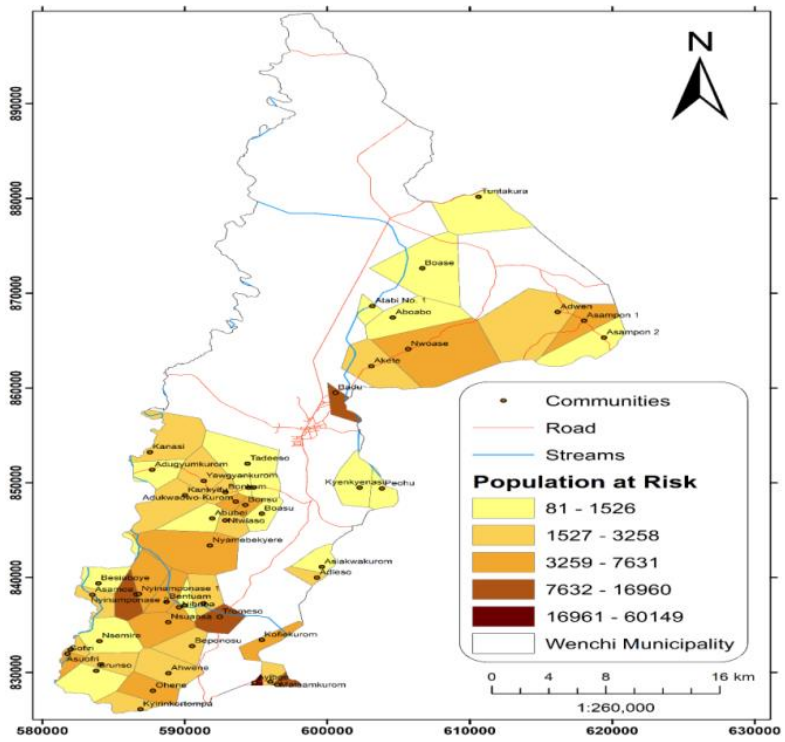


Figure 7. Population at Risk of Maternal Mortality (No Easy Access to Maternal Healthcare)

The findings from the study in Wenchi Municipality, as illustrated in Figures and Table 2 and Table 3, reveal crucial insights into the landscape of maternal healthcare accessibility and vulnerability. The delineated service areas, as demonstrated in Figure 4, showcase a linear catchment around nine health facilities within the municipality, highlighting the areas covered by these facilities through network analysis in ArcGIS Figure 3. However, the subsequent analysis in Figure 6 underscores a significant gap in maternal healthcare accessibility, with only 34 out of 85 communities having easy access, while 51 communities face challenges in accessing maternal healthcare. The vulnerable communities identified in Table 2, such as Kyirinkortompa, Ohene, and Malaamkurom, underscore the localized pockets where maternal healthcare accessibility is particularly compromised.

These communities are geographically dispersed, indicating a need for targeted interventions to bridge the existing gaps. The spatial representation of these vulnerable areas using Thiessen polygons Figure 5 further emphasizes the need for strategic resource allocation and healthcare infrastructure development in these underserved regions. Conversely, Table 3 delineates communities with relatively better access to maternal healthcare services. These areas, including Buko, Kwame Gyankurom, and Amoakurom, represent successes in healthcare accessibility within Wenchi Municipality. Understanding the characteristics of these areas and the factors contributing to their improved accessibility can offer valuable insights for replicable best practices in other regions. The population at risk of maternal mortality, as depicted in Figure 7, underscores the stark reality faced by individuals in communities with limited access to maternal healthcare. The visual representation of vulnerability allows policymakers and healthcare practitioners to prioritize resource allocation, intervention strategies, and infrastructure development in areas where the need is most acute.

It also highlights the urgency of addressing the identified vulnerable communities to mitigate the potential risks associated with maternal mortality. the comprehensive analysis of service areas, vulnerable communities, and populations at risk in Wenchi Municipality provides a detailed understanding of the

current state of maternal healthcare accessibility. This knowledge is instrumental in formulating targeted interventions, policy adjustments, and community-specific healthcare programs to ensure equitable maternal health outcomes across the municipality. The identified gaps and successes can serve as a foundation for evidence-based decision-making and strategic planning to enhance the overall well-being of pregnant women in Wenchi.

4. CONCLUSION

The findings from the geospatial evaluation of maternal healthcare access in Wenchi Municipality illuminate a nuanced landscape of successes and challenges. While the service areas delineated around nine health facilities demonstrate progress in certain regions, the presence of 51 communities lacking easy access to maternal healthcare unveils critical vulnerabilities. The identified vulnerable communities, highlighted through Thiessen polygons and population-at-risk figures, emphasize the urgent need for targeted interventions to bridge existing gaps in accessibility. This study not only contributes to the understanding of localized disparities but also underscores the necessity of context-specific approaches to maternal healthcare planning and resource allocation. The geographic distribution of vulnerable populations provides a foundation for evidence-based decision-making and strategic interventions that consider the unique challenges faced by communities within Wenchi.

4.1 Recommendations for the Municipality

Implementing these recommendations, stakeholders can work towards a more inclusive and resilient maternal healthcare system in Wenchi Municipality, ensuring that no community is left behind in the journey towards improved maternal well-being.

1. **Targeted Infrastructure Development:** Prioritize the development of healthcare infrastructure in vulnerable communities, focusing on the establishment of new health facilities and the improvement of existing ones to enhance accessibility.
2. **Community Engagement Programs:** Implement community-specific awareness and engagement programs to address cultural and social factors influencing maternal healthcare-seeking behaviour. Tailored educational campaigns can empower communities and encourage the timely utilization of maternal health services.
3. **Mobile Health Units:** Explore the feasibility of mobile health units to reach geographically isolated communities, providing on-site maternal healthcare services, antenatal care, and health education.
4. **Data-Driven Policy Adjustments:** Continuously monitor and analyse healthcare accessibility data to inform evidence-based policy adjustments. Regular assessments will help identify changing patterns and ensure dynamic, responsive maternal healthcare planning.
5. **Collaboration with Stakeholders:** Collaborate with local authorities, community leaders, and non-governmental organizations to leverage resources and foster community-driven initiatives. Engaging stakeholders ensures a holistic approach and enhances the sustainability of maternal healthcare interventions.
6. **Regular Monitoring and Evaluation:** Establish a robust monitoring and evaluation system to track the impact of implemented interventions. Regular assessments will enable the refinement of strategies and the identification of emerging challenges.
7. **Integration of Technology:** Explore the integration of technology, such as telehealth services, to overcome geographical barriers. Utilizing digital platforms can facilitate remote consultations and bridge gaps in maternal healthcare access.

Acknowledgments

The authors have no specific acknowledgments to make for this research.

Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Doris Saah	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Jeff Dacosta Osei	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Desmond Karikari Osei	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Lily Lisa Yevugah	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Informed Consent

All participants were informed about the purpose of the study and their voluntary consent was obtained prior to data collection.

Ethical Approval

Not Applicable.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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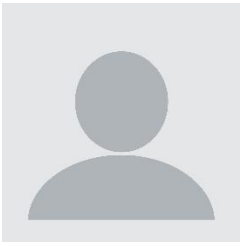
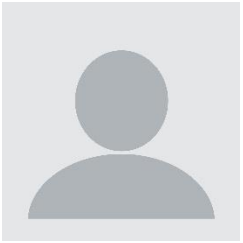
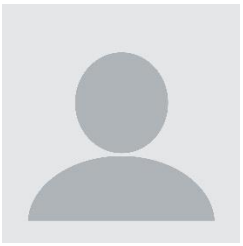
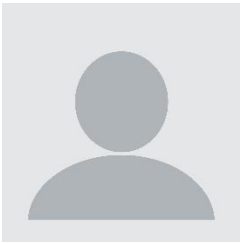
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How to Cite: Doris Saah, Jeff Dacosta Osei, Desmond Karikari Osei, Lily Lisa Yevugah. (2023). Geospatial evaluation of service areas: empowering maternal health for ensuring healthy lives and well-being in the Wenchi Municipality of Ghana. Journal of Nursing Research, Patient Safety and Practice (JNRPSP), 3(2), 85-97. https://doi.org/10.55529/jnrpsp.35.39.52

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