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GEOSPATIAL ANALYSIS OF HEALTH CARE RESOURCE ALLOCATION IN KARUR DISTRICT: INSIGHTS FROM GIS

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ABSTRACT

The Primary Health Care System is essential in delivering critical services such as maternal and child health care, family planning, immunization, provision of essential drugs, and promotion of nutrition and sanitation. In rural areas, effective implementation of primary health care is often hampered by challenges such as inadequate health manpower, entrenched traditional cultural practices, and the dominance of indigenous medicine systems. Additionally, the concentration of health services and personnel in urban areas exacerbates the disparity in healthcare accessibility for rural populations. This study aims to address these disparities by analyzing the spatial distribution of primary health care resources in Karur District current distribution and accessibility of PHCs to health resource allocation. This study addresses these issues by employing Geographical Information System (GIS) techniques to analyze the spatial distribution of primary health care resources in Karur District. By applying Thiessen polygon analysis, we delineate the service areas of Primary Health Centres (PHCs) and evaluate the availability of essential resources, including doctors, staff nurses, auxiliary nurse midwives, and hospital beds. The insights gained from this geospatial analysis highlight the gaps in healthcare provision and offer recommendations for optimizing the allocation of health resources to improve accessibility and service delivery in rural areas.

Keywords: Primary Health Care (PHC), Spatial Distribution, Healthcare Resource Allocation, Thiessen Polygon Analysis, Health Accessibility.

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1. INTRODUCTION

Access to adequate healthcare services is a fundamental right and a critical component of sustainable development, particularly in rural areas where health disparities are often more pronounced. In India, the Primary Health Care (PHC) system is designed to provide essential health services to rural and underserved populations, offering a range of services including maternal and child healthcare, family planning, immunization, provision of essential drugs, and the promotion of nutrition and sanitation. Despite the system's intent and reach, the effectiveness of PHC services in rural areas is frequently undermined by various challenges, including inadequate health manpower, traditional cultural practices, and the concentration of healthcare resources in urban areas (Parvin, F et al 2021; Yerramilli, S et al 2014). These issues create significant disparities in healthcare accessibility and outcomes between rural and urban populations.

Karur District, located in the central part of Tamil Nadu, India, provides a representative case for examining these disparities. The district is characterized by a diverse demographic and geographic landscape, encompassing both urban and rural areas. It has a network of 32 Primary Health Centres (PHCs), 168 health sub-centres, and a Government Medical College Hospital, which collectively aim to meet the healthcare needs of its population. However, the distribution and accessibility of these healthcare resources are uneven, with many rural areas facing challenges in accessing quality health services (Saqib, N et al 2023; Rai et al 2013). Given the central role of PHCs in the healthcare delivery system, it is imperative to analyze their spatial distribution and resource allocation to identify gaps and inform strategies for improvement.

Geographical Information Systems (GIS) offer powerful tools for such an analysis, enabling the visualization and examination of spatial patterns in healthcare resource distribution. GIS-based analysis can provide insights into the areas that are well-served and those that are underserved, allowing for more targeted interventions. In particular, the application of Thiessen Polygon Analysis within GIS allows for the delineation of service areas for each PHC, offering a clear picture of the geographic coverage and identifying regions where additional resources may be needed.

The study integrates various spatial data sources, including population density, existing healthcare facility locations, and transportation networks, to perform spatial queries, overlay analysis, and proximity analysis. By doing so, this research aims to contribute valuable insights to public health planning, particularly in rural areas, and to inform policy decisions that can improve the delivery of healthcare services (Saravanabavan V. 2006; Saravanabavan V 1993; Lakshmi K. 2009) in Karur District and similar regions.

The outcomes of this study are expected to provide a data-driven foundation for addressing the healthcare disparities in Karur District, ensuring that resources are allocated efficiently and equitably. Ultimately, this research underscores the importance of spatial analysis in public health, offering a model that can be replicated in other districts and regions facing similar challenges in healthcare delivery.

2. STUDY AREA

Karur District is located in Tamil Nadu, southern India, with its headquarters in the city of Karur. The district is geographically positioned between 10°45' and 11°45' North Latitude and 77°45' and 78°07' East Longitude, at an altitude of 122 meters. It covers an area of 2,895.57 square kilometers and is centrally located in Tamil Nadu, bordered by Namakkal to the north, Dindigul to the south, Tiruchirappalli to the east, and Erode and Tiruppur to the west. According to the 2011 Census, the district had a population of 1,499,010, with 434,517 living in urban areas and 1,064,493 in rural areas. Karur District is divided into two revenue divisions (Karur and Kulithalai) and five taluks (Karur, Aravakurichi, Kulithalai, Krishnarayapuram, and Kadavoor). It includes eight Community Development Blocks, comprising 170 villages, of which 169 are inhabited.

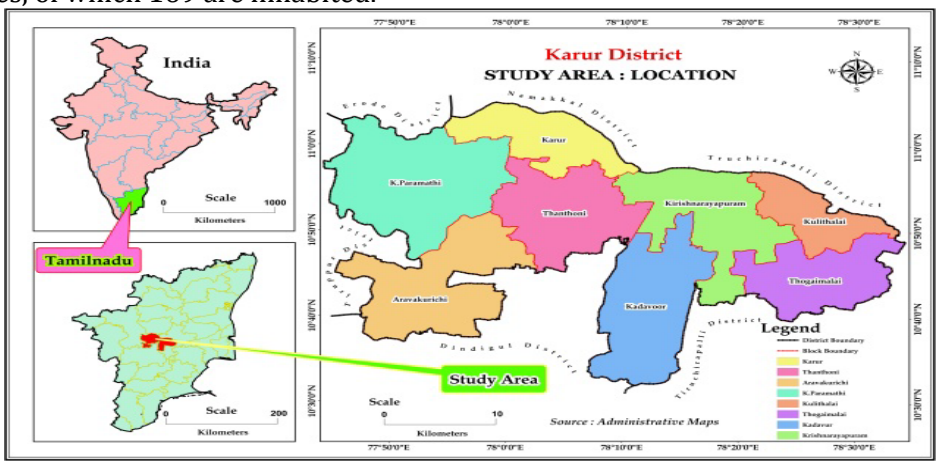

Figure.1 Location map of Study area.

The district experiences a highest temperature of around 34°C in early May to early June, sometimes exceeding 38°C. The average annual rainfall is approximately 775 mm. Karur District is served by 32 Primary Health Centres (PHCs), 168 health sub-centres, and a Government Medical College Hospital. Each PHC typically covers 6-8 villages, catering to the healthcare needs of the rural population within their respective areas. These PHCs are crucial for the district-level implementation of primary healthcare, as recommended by the National Council.

3. OBJECTIVES

This study aims to address these disparities by analyzing the spatial distribution of primary health care resources in Karur District, with the following objectives:

- To assess the current distribution and accessibility of PHCs in Karur District.
- To identify spatial patterns and gaps in the allocation of health care resources.
- To provide recommendations for optimizing health resource allocation to improve accessibility and service delivery in rural areas.

4. METHODOLOGY

This study employs Geographical Information System (GIS) techniques to perform a comprehensive spatial analysis of the health care resource allocation in Karur District.

To achieve the objectives of this study, a comprehensive methodological approach was employed, integrating Geographic Information Systems (GIS) tools and spatial analysis techniques. The first step involved data collection, where geospatial data for the locations of all Primary Health Centres (PHCs) in Karur District were obtained, along with population data at the village or census block level. Additionally, data on transportation networks, including road conditions and distances from villages to the nearest PHCs, were gathered to assess accessibility (Rekha, R. S et al 2017; Vahidnia, M. H et al 2009). Information on healthcare resources, such as the number of doctors, nurses, and hospital beds available at each PHC, was also collected to evaluate the adequacy of healthcare services.

The spatial distribution of PHCs was analyzed using Thiessen Polygon (Voronoi Diagram) analysis in ArcGIS. This technique was applied to delineate the service areas of each PHC, creating polygons that represent the regions where populations are closest to a particular health center (Jones, A. P et al 2019; Murad, A. 2018; Shahba, S et al 2017; Parvin, F et al 2009). To further assess accessibility, network analysis was conducted using the "Network Analyst" extension in ArcGIS, which allowed for the calculation of travel times and distances from population centers to PHCs along existing road networks. Proximity analysis was also performed to evaluate straight-line distances from villages to the nearest PHC, providing a clear picture of geographic accessibility (Luis Rosero-Bixby et al 2004; Higgs, G et al 2004; Smoyer-Tomic K et al 2004;

Van der Heyden, J.H.A. et al 2003; Rosero-Bixby, L. 2003). The availability of healthcare resources was then assessed by calculating ratios, such as the number of doctors, nurses, and beds per 10,000 people, within each Thiessen polygon. These analyses were used to identify spatial patterns and gaps in resource allocation, guiding the development of recommendations for optimizing health resource distribution and improving accessibility across Karur District

THIESSEN POLYGON ANALYSIS

The purpose of thiessen polygon delineate service areas for each PHC by creating polygons around each PHC location, representing the area that is closest to that particular PHC compared to others. This method helps in understanding the spatial coverage of each PHC and identifying areas that are potentially underserved.

Applying Thiessen polygon analysis to delineate the service areas of each PHC. This technique helps in visualizing and understanding the spatial coverage of each health center. Thiessen Polygon Analysis, also known as Voronoi Diagram (K.Chandramohan and Dr.R.Vijaya 2017), is a spatial analysis technique used in geographic information systems (GIS) to divide a region into distinct areas based on proximity to a set of specific points. In this method, each point, such as a Primary Health Centre (PHC), becomes the center of a polygon, with boundaries determined so that any location within a given polygon is closer to its associated point than to any other point in the dataset. This creates a map where each polygon represents the area of influence or service area of the PHC it surrounds. The resulting Thiessen polygons are crucial for assessing and visualizing the spatial distribution of services, resources, or facilities in a region.

In the context of healthcare resource allocation, Thiessen polygons are generated for each PHC to examine the availability pattern of key healthcare staff, including Medical Officers, Staff Nurses, Auxiliary Midwife Nurses (ANM), and Hospital Beds. According to National Rural Health Mission norms (2022), each PHC should ideally have at least 2 Medical Officers, 3 Staff Nurses, 2 ANMs, one lab technician, and 2 Group D workers, with 24x7 access to the study area. By analyzing the polygons, researchers can assess the availability of these health resources by calculating the ratio between healthcare resource components and the population within each service area. This method helps visualize and understand the spatial coverage of each health center, identify potential overlaps or gaps in service areas, and ensure that healthcare resources are equitably distributed according to the population's needs.

RESOURCE AVAILABILITY ASSESSMENT

Evaluating the availability of essential healthcare resources, including doctors, staff nurses, auxiliary nurse midwives, and hospital beds within each service area.

The components of healthcare resources Doctors, Staff Nurses, Auxiliary Midwife Nurses (ANMs), and Hospital Beds per 10,000 persons—were calculated within each Thiessen polygon catchment area to assess the general availability of PHCs. This was done by dividing the number of physicians by the total population within each Thiessen polygon and then multiplying by 10,000 inhabitants. The Thiessen polygons delineate the service area of each Primary Health Centre, revealing the geographic coverage and resource distribution across the study area.

BUFFER ANALYSIS

Buffer analysis is a crucial spatial analysis tool in Geographic Information Systems (GIS) that helps assess the accessibility of services, such as healthcare, by creating zones around specific locations, like Primary Health Centres (PHCs). By examining the distance between service points and surrounding areas, buffer analysis identifies regions with varying levels of access to essential services.

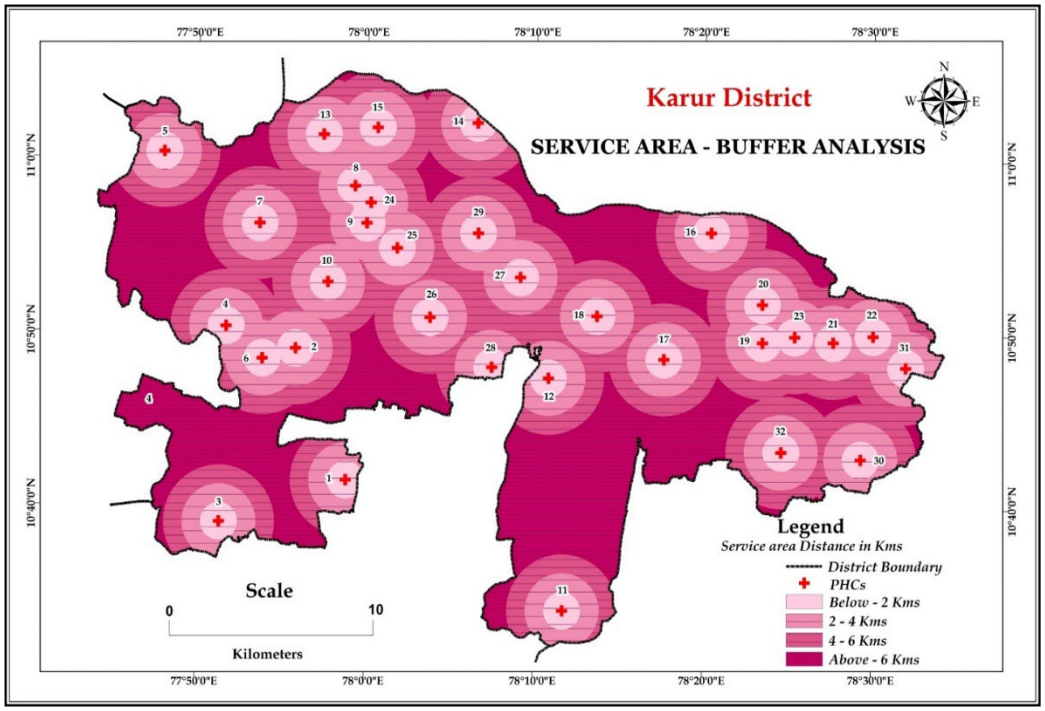

Figure.2 Accessibility of buffer range of village to PHC

This method is particularly important in public health planning as it allows policymakers and planners to visualize and quantify the extent to which populations are served by healthcare facilities. It helps in identifying underserved areas, guiding the allocation of resources, and ensuring equitable access to services across a region. In essence, buffer analysis supports informed decision-making aimed at improving service delivery and addressing disparities in access.

Table.1 Service Area - Buffer Analysis - PHCs

S.No	Service area - Distance in Km	Number of Villages	% of Villages	Population	% of Population
1	Below - 2 Km	29	17	262527	32
2	2 - 4 Km	37	22	115775	14
3	4 - 6 Km	63	37	264553	32
4	Above - 6 Km	40	24	176504	22
	Total	**169**	**100**	**819359**	**100**

The buffer analysis of Primary Health Centres (PHCs) in Karur District reveals varying levels of healthcare accessibility based on distance. Villages within a 2 km radius of a PHC, accounting for 17% of the villages and 32% of the population,

enjoy the best access to healthcare, ensuring that a significant portion of the population can reach medical services with ease. As the distance increases to 2-4 km, accessibility becomes moderate, encompassing 22% of the villages and 14% of the population, where residents still have relatively good access to healthcare facilities. However, in the 4-6 km range, where 37% of the villages and another 32% of the population reside, access becomes strained, with challenges growing more apparent. The situation poor for those living more than 6 km away from a PHC, representing 24% of the villages and 22% of the population, where accessibility is poor, likely leading to delays in medical care and increased health risks. These findings highlight the need for targeted interventions to improve healthcare access, particularly in the more remote areas of the district.

AVAILABILITY OF DOCTORS

Doctors serve as the heads of the health teams in Primary Health Centres (PHCs), practicing medicine to ensure human health through the study, diagnosis, and treatment of diseases and other physical and mental conditions. Their responsibilities include attending to patients at the PHC during the morning and supervising fieldwork in the afternoon. They also visit each Health Sub-Centre regularly on fixed days and hours to provide guidance, supervision, and leadership to the health team. Additionally, doctors spend one day each month organizing staff meetings at the PHC to discuss problems and review the progress of health activities, ensuring that national health programs are being properly implemented in their area. Figure.2 likely shows the spatial distribution of doctors across different Primary Health Centres (PHCs) in the study area. Areas with a higher concentration of doctors would be highlighted, possibly indicating better access to medical care in those regions. Conversely, regions with fewer doctors might be shown as underserved, indicating a need for additional medical personnel

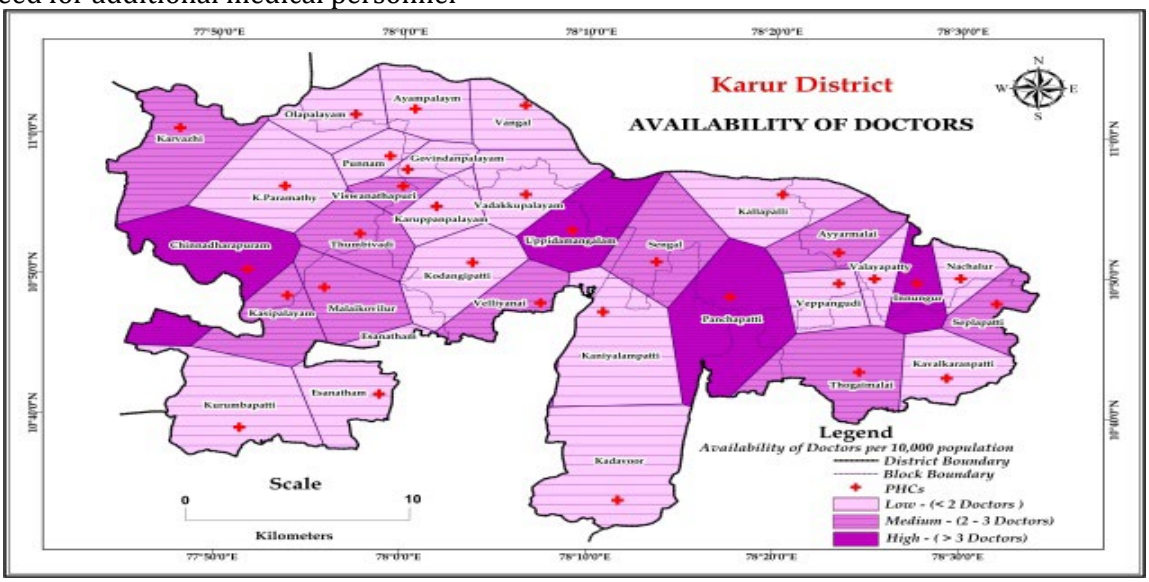

Figure 3: Doctors Availability

According to National Rural Health Mission norms, each PHC should have two doctors: one general practitioner and one lady doctor. In the study area, 138 doctors are currently serving in PHCs. To assess the availability pattern of doctors in each PHC, the Doctors-to-Population ratio was calculated and categorized into three groups: low (below 2 doctors per 10,000 population), medium (2-3 doctors per 10,000 population), and high (above 3 doctors per 10,000 population). This analysis reveals the varying levels of doctor availability across the study area.

AVAILABILITY OF STAFF NURSES

Figure.4 illustrates the distribution of staff nurses across the PHCs. It might show which areas have sufficient nursing staff as per the norms of the National Rural Health Mission and which areas may be lacking. Regions with fewer staff nurses could be identified as requiring more resources to meet healthcare needs. Staff nurses primarily provide preventive healthcare, maternal and child care, immunization, detection of communicable diseases, health education for disease prevention, environmental sanitation, and family planning motivation. They are often the first point of contact for patients and visitors in hospitals or other medical facilities, where they record patients' concerns, assess their medical conditions, and report findings to the doctor.

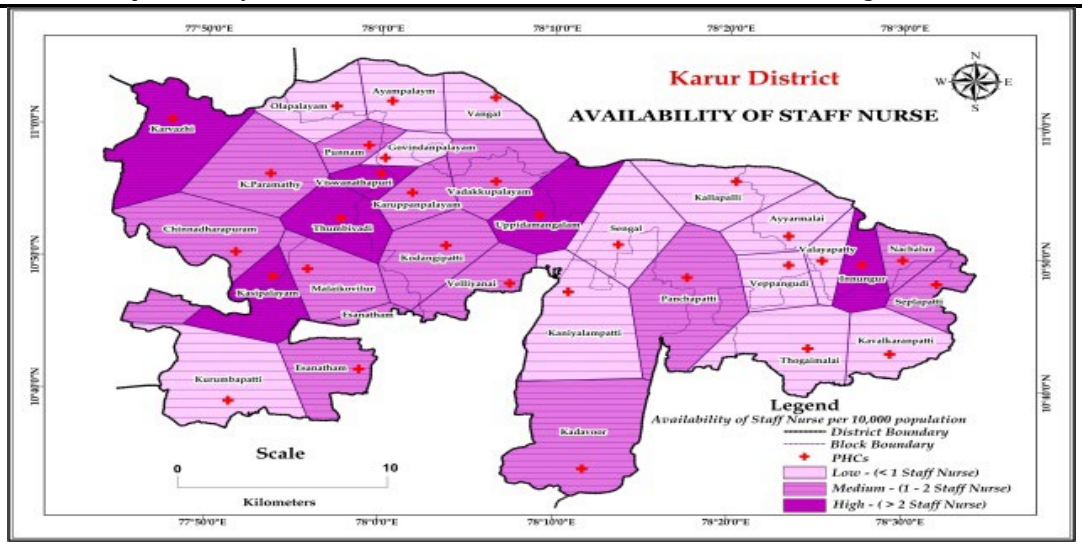

Figure 4: Availability of staff nurse

The Staff Nurse-to-Population ratio has been calculated and categorized into three groups: low (below 1 Staff Nurse per 10,000 population), medium (1 to 2 Staff Nurses per 10,000 population), and high (above 3 Staff Nurses per 10,000 population)

AVAILABILITY OF AUXILIARY NURSE MIDWIVES (ANM)

The Auxiliary Nurse Midwife (ANM) plays a vital role in supervising and guiding health workers in the delivery of health services to the community, particularly in rural areas. As the most effective health worker for delivering primary health care in these regions, ANMs often come from rural backgrounds, speak the local language, understand the local culture, and value community participation. They maintain maternity records, immunize pregnant women, supervise deliveries, and provide family planning advice and motivation to couples. Additionally, ANMs educate the community on sanitation, safe drinking water, and nutrition. In the district, there are 77 Auxiliary Nurse Midwives..

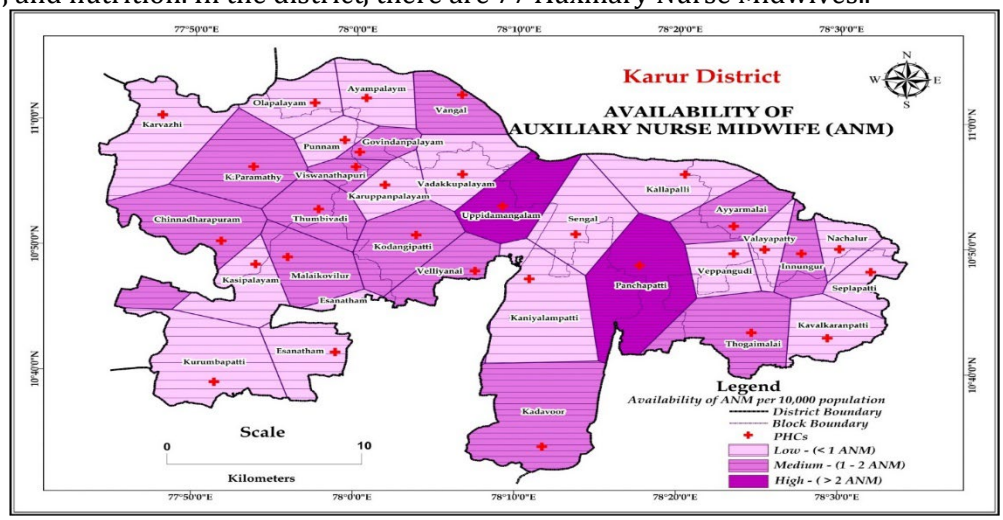

Figure 5: Availability of Auxiliary Nurse Midwives

This map probably displays the availability of Auxiliary Nurse Midwives (ANMs) within the PHCs. ANMs play a critical role in maternal and child health services, so the map might highlight areas where their presence is strong or where additional ANMs are needed to improve health outcomes. The availability of ANMs is categorized into three levels: low (below 1 ANM per 10,000 population), medium (1 to 2 ANMs per 10,000 population), and high (above 2 ANMs per 10,000 population). Uppidamangalam and Panchapatti Primary Health Centres have a high availability, with more than 2 ANMs per 10,000 population

AVAILABILITY OF BEDS

Figure 6 shows the distribution of hospital beds across the PHCs, indicating the capacity of each health center to accommodate patients. Areas with a higher number of beds would be able to serve more patients, while areas with fewer beds might struggle to meet demand, especially during health emergencies. There are 324 beds available in the Primary Health Centres across the district, and the Bed-to-Population ratio has been calculated. This ratio is categorized into three levels of availability: low (below 2 beds per 10,000 population), medium (2 to 3 beds per 10,000 population), and high (above 3 beds per 10,000 population)

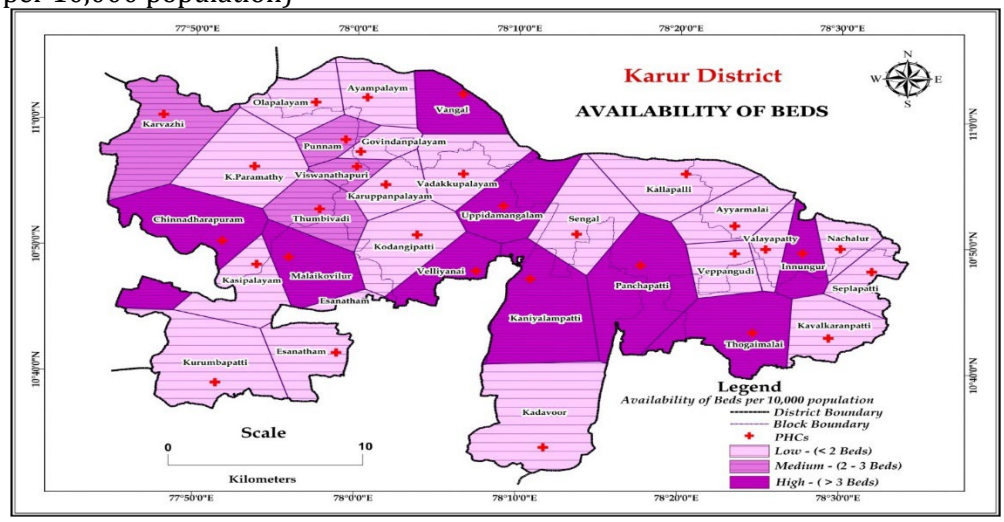

Figure 6: availability of beds

Table.1 Availability of Health Resources in PHCs (Thiessen Polygon Method)

S.No	Blocks	PHC	Population	HSC	Doctors	Staff Nurse	ANM	Bed
1	Aravakurichi	Esanatham	14443	6	2	3	1	2
2	Aruvakurichi	Malaikovilur	37933	6	8	6	5	30
3	Aravakurichi	Kurumbapatti	44444	6	5	3	1	2
4	K.Paramathy	Chinnadharapuram	18124	4	6	4	3	30
5	K.Paramathy	Karvazhi	10829	4	2	3	1	3
6	K.Paramathy	Kasipalayam	10014	3	2	3	1	2
7	K.Paramathy	K. Paramathy	16767	4	2	4	2	3
8	K.Paramathy	Punnam	12486	3	2	3	1	3
9	K.Paramathy	Viswanathapuri	9840	2	2	3	1	2
10	K.Paramathy	Thumbivadi	7062	2	2	3	1	2
11	Kadavur	Kadavoor	38891	7	5	6	4	3
12	Kadavur	Kaniyalampatti	55749	11	6	5	5	30
13	Karur	Olapalayam	44929	9	3	1	1	2
14	Karur	Vangal	38003	7	6	3	4	30
15	Karur	Ayampalayam	34521	12	5	2	2	3
16	Krishnarayapuram	Kallapalli	61956	9	8	6	3	2
17	Krishnarayapuram	Panchapatti	24740	6	8	5	5	30
18	Krishnarayapuram	Sengal	27703	7	5	2	2	2
19	Krishnarayapuram	Veppangudi	21221	5	2	1	1	2
20	Kulithalai	Ayyarmalai	25391	5	5	2	3	3
21	Kulithalai	Innungur	19325	3	6	6	3	30
22	Kulithalai	Nachalur	24664	4	3	5	2	2
23	Kulithalai	Valayapatty	17525	3	2	2	1	2
24	Thanthoni	Govindanpalayam	25817	3	3	2	3	3

25	Thanthoni	Karuppanpalayam	13570	6	2	3	1	2
26	Thanthoni	Kodangipatti	15589	3	2	3	2	3
27	Thanthoni	Uppidamangalam	13947	4	8	6	5	30
28	Thanthoni	Velliyanai	22991	4	6	5	3	30
29	Thanthoni	Vadakkupalayam	18133	4	2	3	1	2
30	Thogaimalai	Kavalkaranpatti	30524	5	5	4	3	2
31	Thogaimalai	Seplapatti	23718	5	5	5	1	2
32	Thogaimalai	Thogaimalai	38510	6	8	5	5	30

RECOMMENDATION FOR DOCTOR AVAILABILITY

There is a need to increase the number of doctors in PHCs to meet the NRHM's minimum standards, ideally moving the overall ratio closer to or above 2 doctors per 10,000 population.

- Short-Term Solution: Redistribute existing healthcare resources more efficiently or consider temporary solutions like telemedicine to mitigate the shortage.
- Long-Term Strategy: Hiring additional medical officers and ensuring every PHC meets the required staffing levels would significantly improve healthcare access and quality in Karur District.

RECOMMENDATION FOR STAFF NURSE AVAILABILITY

- Improve Availability: To fully meet the NRHM norms, efforts should be made to increase the number of staff nurses in PHCs to push the ratio closer to or above 2 staff nurses per 10,000 population.
- Long-Term Strategy: Hiring additional staff nurses will be necessary to ensure that each PHC is adequately staffed to meet the healthcare needs of the population.

RECOMMENDATION FOR ANM AVAILABILITY

- Action Required: There is a clear need to increase the number of ANMs in the PHCs across Karur District to meet the NRHM's recommended levels. The overall shortage could impact the delivery of critical maternal and child health services, immunization, and community health education.
- Long-Term Strategy: Recruiting additional ANMs and ensuring their equitable distribution across all PHCs would be essential for improving healthcare access and quality in the district.

RECOMMENDATION BED AVAILABILITY

- Good Bed Availability: The current Bed-to-Population ratio of approximately 3.95 beds per 10,000 people, the bed availability in Karur District's PHCs is classified as high, PHCs are well-equipped in terms of bed availability, and no immediate action is required to increase this capacity.
- Maintain Standards: It is recommended to maintain this level of availability and ensure that the quality of care associated with these beds is consistently high.

5. CONCLUSION

Based on the current Doctor-to-Population ratio, there is a shortage of doctors in Karur District's PHCs, and measures should be taken to address this gap to ensure adequate healthcare services are available to the population. The insights gained from this geospatial analysis will highlight the existing gaps in healthcare provision in Karur District, offering evidence-based recommendations for policymakers to optimize health resource distribution and enhance service delivery in rural areas. This study underscores the importance of spatial analysis in public health planning, particularly in addressing the unique challenges faced by rural healthcare systems. The current Staff Nurse-to-Population ratio indicates that staff nurse availability is fair but not optimal. The district falls within the medium range. Efforts should be made to increase the number of staff nurses to ensure more comprehensive coverage and better healthcare outcomes in the region. The current ANM-to-Population ratio is below the recommended standard, indicating a significant shortage of ANMs. While some PHCs like Uppidamangalam and Panchapatti have sufficient ANMs, the district as a whole requires more ANMs to adequately meet the healthcare needs of the population. This shortage should be addressed to improve overall healthcare service delivery in the region. The bed availability in Karur District's PHCs is good, with the district exceeding the medium threshold and falling into the high availability category. This suggests that the PHCs are well-

prepared to accommodate patients in terms of bed capacity, and there is no immediate need to increase the number of beds based on the current population size.

Conducting overlay and proximity analysis in GIS tools used to identify areas with inadequate access to healthcare services. Analyzing the geographic disparities in healthcare provision and developing actionable recommendations for improving resource allocation and accessibility in underserved areas.

CONFLICT OF INTERESTS

None

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None

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