KADUNA JOURNAL OF GEOGRAPHY
2025, VOL. 7, No. 1, 157-164
https://doi.org/10.47514/kjg.2025.07.01.018

SPECIAL ISSUE: CELEBRATING 20 YEARS OF GEOGRAPHY IN KADUNA STATE UNIVERSITY - ADVANCES AND FRONTIERS IN GEOGRAPHY

Geospatial Inequities in Access to Public Primary Healthcare Centers: Socioeconomic Vulnerability and Policy Drivers in Kaduna State, Nigeria

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ABSTRACT
This study evaluates the spatial justice of Public Primary Healthcare Centres (PPHCs) distribution across Kaduna State's 255 electoral wards, critiquing the rigid "one PPHC per ward" mandate. Using a mixed-methods approach, Geographic Information Systems (GIS) mapping was integrated with a household survey (N=400). Results reveal a systemic mismatch: while 100% of wards have a facility, only 42% meet national population-to-facility standards. Severe overcrowding exists in the North (72.41%) and Central (83.95%) zones, with ratios exceeding 1:40,000. ANOVA results ($F=18.42$, $p < 0.001$) confirm significant zonal disparities in access quality. Furthermore, Pearson Correlation identified a "Proximity-Poverty Paradox," where household income ($r = 0.64$) and transport costs ($r = -0.58$) are stronger predictors of access than distance among the 87.96% living in poverty. The study concludes that current administrative allocation prioritizes territorial equality over equity of outcome. Policy must transition toward GIS-guided Maximum Coverage Location Models (MCLM) and aggressive expansion of the Kaduna State Contributory Health Management Authority (KADCHMA) to decouple healthcare access from income and achieve Universal Health Coverage.

ARTICLE HISTORY
Submitted 24 October 2025
Accepted 22 December 2025
Published 25 December 2025

GUEST EDITOR
A. M. Ahmed

KEYWORDS
Geographic Information Systems (GIS); Healthcare Policy; Socio-economic vulnerability; Sustainable Development Goals (SDGs); Universal Health Coverage (UHC); Ward Health System (WHS)

1 Introduction

Equitable access to healthcare is a foundational pillar of Sustainable Development Goal 3 and the global movement toward Universal Health Coverage (UHC), which envisions a system where all individuals receive essential services without incurring catastrophic financial hardship (World Health Organization [WHO], 2025). Despite these global mandates, profound disparities in healthcare access persist, particularly within low- and middle-income countries (LMICs) where spatial, economic, and infrastructural constraints remain acute (WHO, 2023).

Regionally, Sub-Saharan Africa continues to struggle with structural impediments to UHC, characterized by rapid, often unplanned urbanization, prohibitive travel distances in rural hinterlands, and an uneven distribution of health infrastructure (Sidze et al., 2022). These factors coalesce to create marked urban-rural and socio-economic divides, where geographic location frequently determines the quality and frequency of healthcare utilization.

In Nigeria, the strategic framework for decentralized healthcare delivery is the Ward Health System (WHS). This policy mandates the establishment of at least one public Primary Healthcare Centre (PHC) within each administrative ward to ensure grassroots coverage (National Primary Health Care Development Agency [NPHCDA], 2021). However, while the WHS is designed to foster equity, its rigid adherence to administrative boundaries often ignores critical demographic nuances such as population density, settlement morphology, and localized socioeconomic vulnerability. Scholars have characterized this approach as "spatially blind," as it inadvertently creates a functional imbalance: overcrowded facilities in dense urban corridors and physical isolation for residents in sparsely populated rural districts (Idoko, 2021; Michael & Alonge, 2021).

In Kaduna State, a major demographic hub in Northern Nigeria, these systemic mismatches are particularly pronounced. Although the state has achieved nominal facility presence across its wards, "effective access" remains elusive for the majority. With approximately 88% of the population living below the poverty line, out-of-pocket health expenditures act as a formidable barrier, even when a facility is geographically near (World Bank, 2022).

This study utilizes Geographic Information Systems (GIS) integrated with household survey data to evaluate the functional effectiveness of the Ward Health System in Kaduna State. By reframing healthcare accessibility through the conceptual lens of spatial justice, the research challenges the status quo of administratively driven allocation. It provides an empirical basis for transitioning toward a more dynamic, population-centered, and need-based planning model for healthcare infrastructure.

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1.1 Thematic Framework: The Multi-Dimensionality of Access

Following the framework of Penchansky and Thomas (1981), healthcare access is defined by five dimensions: Availability, Accessibility, Accommodation, Affordability, and Acceptability. While global scholarship in Sub-Saharan Africa (SSA) has historically focused on physical Accessibility (travel distance), recent evidence suggests that Affordability and Availability (service-to-population ratios) are equally critical barriers to UHC (Levesque et al., 2013). In regions like Kaduna, physical proximity is often decoupled from effective access due to extreme socioeconomic vulnerability and high out-of-pocket spending (Eze et al., 2022).

Geospatial modeling in SSA and parts of Asia consistently identifies significant deficits in rural healthcare coverage driven by poor road networks and seasonal impassability (Macharia et al., 2017; Cao et al., 2021). However, a recurring gap in existing literature is the tendency to treat facility locations as "fixed" or purely geographical entities, overlooking the political and administrative drivers of their placement (Bell et al., 2014). For example, while studies in India and Nepal highlight terrain-driven gaps, they rarely critique the sub-national policies similar to Nigeria's WHS that mandate facility distribution based on political rather than demographic metrics (Verma & Dash, 2020).

While the Ward Health System (WHS) has successfully increased Nigeria's nominal healthcare facilities, a persistent disconnect remains between facility presence and functional service quality (Okoli et al., 2020). The prevailing "one-size-fits-all" allocation strategy fails to account for the extreme demographic heterogeneity between hyper-dense urban centres and sparse rural peripheries (Abubakar, 2021). Regional analyses by Abdullahi et al. (2024) and Babatimehin et al. (2011) demonstrate that PHCs frequently cluster along major transport arteries or follow political and ethnic jurisdictions, leaving peripheral populations underserved despite the "one per ward" mandate. However, these studies remain largely descriptive and lack a sub-national focus that integrates granular socioeconomic conditions into a formal policy critique.

Historically, scholarship in this domain has been bifurcated: Chiemelu and Adewara (2024) and Damashi et al. (2020) prioritize GIS-based proximity mapping, while Nwokoro et al. (2022) focus on the socioeconomic determinants of utilization. By isolating these dimensions, extant literature offers limited insight into how administrative rigidity interacts with extreme poverty to create "pockets of exclusion" within formally served wards. This study fills that gap by synthesizing statewide GIS modelling with granular household data. Moving beyond mere cartographic description (Adewoyin et al., 2016; Averik et al., 2024), it interrogates the "political logic" of the WHS. Framed by Young's (1990) model of spatial justice, this research argues that equitable outcomes, rather than mere administrative coverage, must serve as the primary driver for sub-national healthcare planning.

2 Materials and Methods

2.1 Study Area

The research was conducted in Kaduna State, Nigeria, located between latitudes 9°00' N and 11°32' N, and longitudes 6°00' E and 8°48' E (Averik, 2023) (see Figure 1 below). According to the 2006 census, it is Nigeria's third most populous state, with approximately 6.06 million residents (NPC, 2009). Recent estimates indicate that by 2023, the population will have increased to around 10.41 million (World Bank, 2023), based on previous census data and assessments by relevant government agencies (KDSG, 2017). The state's area is approximately 45,711.2 km² (KDSG, 2010, 2012). It is culturally diverse, including various religions, ethnic groups, traditions, and social values. The Hausa ethnic group inhabits the northern part and is predominantly Muslim, while the southern region is more ethnically mixed and mainly Christian (KDSG, 2010 & 2017). Kaduna has a tropical climate with distinct dry and wet seasons. According to the Köppen classification system, it is classified as Aw, indicating a tropical savannah climate (Abaje, 2007; Abaje et al., 2015). The average annual rainfall is about 1323 mm (Oladipo, 1993).

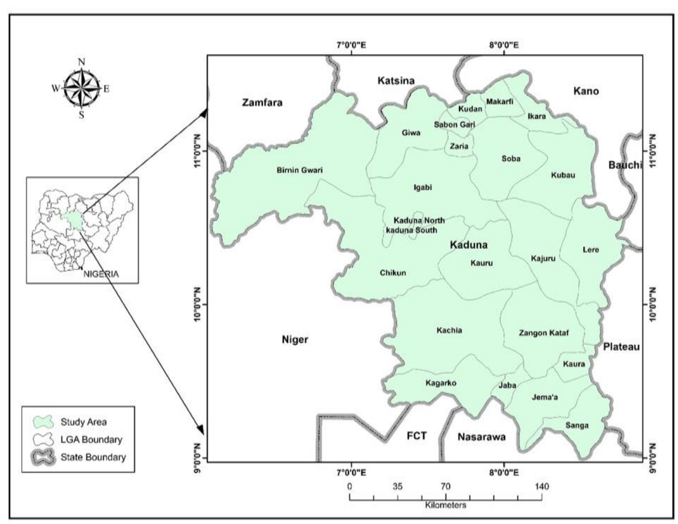

Figure 1: Kaduna State showing Local Government Areas (study area)
Source: Adapted from the Administrative Map of Kaduna State

2.2 Data Collection

The study adopted a mixed-methods research design, integrating geospatial analysis with a cross-sectional household survey to evaluate healthcare accessibility through the lens of Spatial Justice. This framework allows for a comprehensive critique of the "one PPHC per ward" policy by triangulating physical location data with the socioeconomic realities of the population.

The study area was first stratified into its three senatorial zones (North, Central, and South) to ensure the representation of regional diversity. A multi-stage stratified random sampling procedure was then employed, selecting three Local Government Areas (LGAs) per zone to reflect high, medium, and low population densities: Zaria, Soba, and Kudan in the North; Igabi, Kaduna North, and Kajuru in the Central zone; and Zangon-Kataf, Kagarko, and Sanga in the South. Within these LGAs, wards were selected using systematic random sampling, identifying every third ward alphabetically. Finally, a systematic household survey was conducted within the selected wards to capture socioeconomic dimensions and "perceived access" to healthcare services.

The study utilized a sample size of n=400 households, derived using Yamane's (1967) formula for finite populations. This determination was cross-validated by Cochran's (1963) recommendations for large populations at a 95% confidence level, ensuring sufficient statistical power and a 5% margin of error. This dual-model approach maintains a robust equilibrium between methodological rigor and operational feasibility (Kothari, 2004).

To provide a multi-dimensional view of accessibility, this study employed a mixed-methods approach that integrated spatial and socioeconomic datasets. The geospatial mapping of Public Primary Healthcare Centres (PPHCs) was conducted using handheld Global Positioning System (GPS) devices to obtain precise coordinates for all 255 facilities; these points were then georeferenced and validated against Kaduna State Primary Health Care Board records for accuracy. To estimate current ward-level densities, ward-level shapefiles and population projections were extrapolated by triangulating data from the National Population Commission (NPC, 1991, 2006) with the WorldPop dataset.

A structured household questionnaire utilized a 5-point Likert scale to measure the "Five A's" of access (Availability, Accessibility, Affordability, Adequacy, and Acceptability), as conceptualized by Penchansky and Thomas (1981). The instrument also collected quantitative data on key accessibility indicators, including household income, transport costs, and travel time. The tool underwent a comprehensive expert review and a pilot study to refine its clarity and relevance. Internal consistency and reliability were statistically confirmed using Cronbach's Alpha, which yielded a coefficient of 0.89, a value significantly exceeding the standard 0.70 threshold for research reliability (Nunnally & Bernstein, 1994).

2.3 Data Analysis

ArcGIS software was utilized to develop a geodatabase for spatial analysis, beginning with a Point-in-Polygon Analysis to determine the exact number of PPHCs within each electoral ward. Ratio Mapping was then applied to calculate population-to-facility ratios, benchmarked against the WHO/FGN standard of 1:30,000 (WHO, 2010; FGN, 2012). To evaluate physical accessibility, Euclidean distance was calculated using the Near tool, measuring the straight-line distance from ward centroids to the nearest PHC. This method was selected over network analysis due to the lack of comprehensive road network data for rural and peri-urban Kaduna, serving as a reliable and consistent proxy for travel proximity (Guagliardo, 2004; Noor et al., 2006).

For the statistical analysis, a One-Way ANOVA was employed to identify significant differences in healthcare access scores across the three senatorial zones, testing whether the "one PHC per ward" policy resulted in uniform accessibility. Additionally, Pearson correlation (r) was used to examine the linear relationships between socio-demographic variables, specifically household income and transport costs, and perceived access. This analysis was critical for identifying the "Proximity-Poverty Paradox," determining whether economic status functioned as a more significant barrier to healthcare than physical distance.

Findings were triangulated to align with the WHO (2017) framework. Benchmarking household income against the international poverty line revealed that 87.96% of respondents live below this threshold, highlighting how economic vulnerability compounds spatial inequities in Kaduna State.

3 Results and Discussion

The analysis reveals a systemic disconnect between the "one Primary Health Care (PHC) per ward" mandate and Kaduna State's actual demographic needs. This administrative rigidity has produced a landscape of spatial inequality where nominal presence does not equate to effective access.

3.1 Spatial Mismatch and the "One PHC per Ward" Paradox

Of the 255 evaluated PHCs, only 42% adhere to the national 1:30,000 population-to-facility standard. While the Southern Zone shows a "Fair" ratio, 72.41% of facilities in the North and 83.95% in the Central Zone suffer from severe service pressure. ANOVA results ($F=18.42$, $p < 0.001$) provide empirical proof that this model is structurally incapable of ensuring equitable distribution.

As illustrated in Figure 2 below, several wards, especially in the Northern and Central zones, exhibit alarmingly high ratios exceeding 1:40,000. This is significantly above the WHO/FGN recommended standard of 1:10,000 to 1:30,000 (WHO, 2010; FGN, 2012). This spatial mismatch suggests that the policy of distributing facilities based on political boundaries rather than population density effectively penalizes residents in high-growth urban corridors.

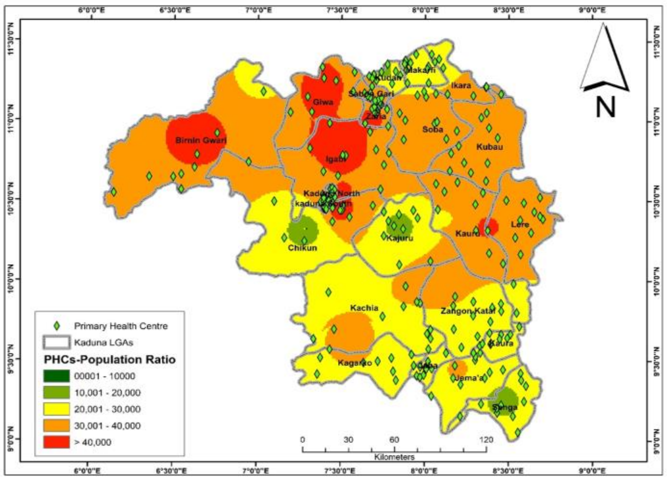

Figure 2: Kaduna state showing the spatial distribution of PHCs and Population-to-Facility Ratios

The map above illustrates the disparity in service coverage, highlighting wards in the North and Central zones where ratios exceed the national 1:30,000 threshold.

- Kaduna North Zone: Out of 87 PHCs, only 24 meet optimal ratios. Ten of the 13 PHCs in Zaria LGA have a "very poor" ratio of 1:>40,000.
- Kaduna Central Zone: 36 of 81 PHCs, mostly in the Kaduna metropolis, are classified as "very poor," serving over 40,000 people per facility.
- Southern Zone: Demonstrates "fair" accessibility, with 70 PHCs meeting the criteria, though physical distance remains a hidden barrier.

This confirms the work of Yusuf (2018), who argued that uniform distribution models are inherently flawed in regions with high demographic variability. By prioritizing "territorial equality" over "equity of outcome," the policy inadvertently penalizes dense urban clusters in Zaria and the Kaduna metropolis.

3.2 Population Density and the "Proximity-Poverty Paradox"

The study found no statistically significant difference in PHC density relative to overall population distribution, despite clear disparities in density shown in Figure 3 below.

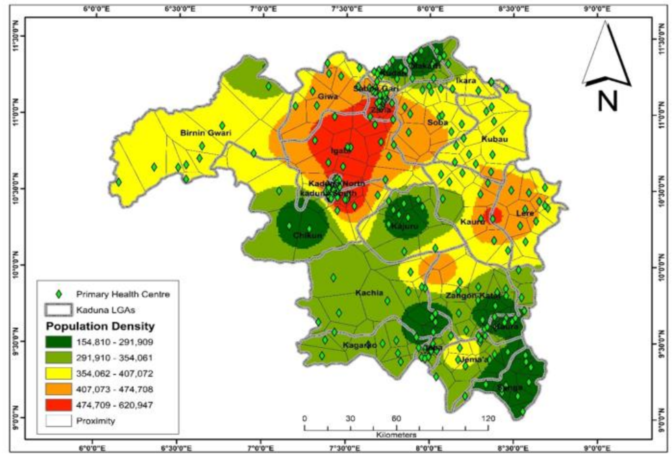

Figure 3: Kaduna State Showing Population Density Gradients

Figure 3 above displays the extreme demographic variation across the state, identifying the high density-urban clusters that drive service pressure in existing healthcare centres. Urban clusters like Kaduna metropolis and Zaria have densities reaching over 620,000 people per km². In contrast, rural wards display moderate to low densities. This uniformity in PHC siting, dictated by the 255 electoral wards, creates a disconnect:

- Urban Overcrowding: High-density areas face declining service quality and long wait times.
- Rural Impedance: In the Southern Zone, while ratios look "fair" on paper, residents face "spatial impedance," traveling long distances over tough terrain.

Pearson Correlation analysis ($r = -0.74$, $p < 0.01$) highlights a "proximity-poverty paradox": while policy focuses on physical distance, economic vulnerability is the more significant determinant of access. This aligns with Adewuyi et al. (2019), who noted that for underserved populations, distance acts as a "compounding financial barrier" due to high indirect costs.

3.3 Socio-Demographic Findings and Policy Drivers

The household survey (N=400) provides the "why" behind the spatial data.

Poverty Levels: A staggering 87.96% of respondents live below the international poverty line ($2.15/day).

Transport Vulnerability: These residents rely on motorcycles and tricycles; the strong inverse relationship between income and transport dependence directly impacts their ability to reach distant PHCs.

Intersectionality: Socioeconomic vulnerability intersects with sociocultural norms. In specific LGAs, gender-based barriers further hinder women's access, consistent with Ganle et al. (2014).

The politically driven siting of PHCs serves as an "administrative convenience" that ignores the reality that poverty acts as a non-spatial barrier ($r = 0.64$ for income and access). These findings demand a shift toward Spatial Justice, where resource allocation is prioritized for low-income, high-density wards through evidence-based models like Maximum Coverage Location Models (MCLM).

3.4 Statistical Results

The geospatial inequities identified in Figures 2 and 3 are further validated by inferential and correlational statistics, which quantify the extent of healthcare disparity across Kaduna State.

3.4.1 Variance in Access Scores (ANOVA)

A One-Way ANOVA confirms statistically significant disparities in healthcare access scores across the three senatorial zones, particularly highlighting the disadvantage of the Central and North zones compared to the South.

Table 1: One-Way ANOVA of Healthcare Access Scores by Senatorial Zone

Source of Variation	Sum of Squares	Df	Mean Square	F-value	p-value	Effect Size (n^2)
Between Groups	412.55	2	206.27	18.42	< 0.001	0.085
Within Groups	4442.10	397	11.19			
Total	4854.65	399				

Note: Significant at $p < 0.05$. The effect size ($n^2 = 0.085$) indicates a medium effect of geographic location on perceived accessibility.

3.4.2 Correlation of Socio-Demographics and Perceived Access

Pearson correlation analysis was performed on socioeconomic variables and perceived accessibility. The data shows a strong positive correlation between income and access, reinforcing the finding that 88% of the population's poverty levels act as a non-spatial barrier to care.

The 95% Confidence Intervals for income [0.58, 0.70] suggest this relationship is highly stable. This statistically confirms that Affordability is as significant a barrier as distance. To achieve Universal Health Coverage (UHC), Kaduna State must move beyond the "one ward, one PHC" political metric and adopt a needs-based strategy that accounts for population density and economic vulnerability.

Table 2: Pearson Correlation Matrix for Accessibility and Socio-Demographic Variables

Variable	1	2	3	4	95% CI [LL, UL]
1. Perceived Access Score	1.00				—
2. Household Income	0.64	1.00			[0.58, 0.70]
3. Literacy Level	0.32	0.28	1.00		[0.23, 0.40]
4. Transport Cost	-0.58	-0.45	-0.12	1.00	[-0.64, -0.51]

Note: Correlation is significant at the 0.01 level (2-tailed). N = 400. CI = Confidence Interval; LL = Lower Limit; UL = Upper Limit.

The statistical results presented in Tables 1 and 2 provide empirical weight to the geospatial inequities identified. The ANOVA results (F=18.42, p<0.001) indicate that the "one PHC per ward" policy does not produce a uniform experience of healthcare access across Kaduna State. Instead, the senatorial zone is a significant predictor of access quality.

Furthermore, the Pearson Correlation reveals that Household Income (r = 0.64) and Transport Cost (r = -0.58) are the most powerful predictors of perceived access. This statistically confirms that in a population where 87.96% live below the poverty line, Affordability (from the Five A's framework) is as significant a barrier as distance. The 95% Confidence Intervals for income (0.58, 0.70) suggest that this relationship is highly stable and not a result of sampling bias. These findings demand a shift toward Spatial Justice, where resource allocation is skewed toward low-income, high-density wards rather than distributed evenly across political boundaries.

3.5 Translating Findings into Policy Implications

The empirical evidence suggests that the "one PPHC per ward" mandate is an administrative convenience that fails to address the "Proximity-Poverty Paradox." The strong correlation between income and access (r = 0.64) implies that infrastructure alone cannot achieve Universal Health Coverage for a population where 88% live in poverty.

Consequently, the role of the Kaduna State Contributory Health Management Authority (KADCHMA) is critical; financial protection must be prioritized alongside physical construction to decouple healthcare utilization from household income. Furthermore, the significant zonal disparities confirmed by ANOVA (F=18.42) necessitate a transition from politically-bounded siting to Maximum Coverage

Location Models (MCLM). This shift would ensure that resource allocation is skewed toward high-density, high-vulnerability clusters rather than distributed uniformly across 255 disparate electoral wards.

4 Conclusion

This study demonstrates that the "one PPHC per ward" mandate in Kaduna State, while politically expedient, is geographically and demographically insufficient. The findings confirm a profound spatial mismatch: while 100% of wards may have a facility, only 42% of these facilities meet the national standard for population-to-facility ratios. The statistical evidence from ANOVA ($F=18.42$, $p < 0.001$) and Pearson Correlation ($r = 0.64$) highlights that healthcare access in Kaduna is not merely a matter of physical distance, but a complex intersection of demographic pressure and socioeconomic vulnerability.

The "Proximity-Poverty Paradox" identified in this research reveals that for the 87.96% of the population living below the poverty line, a PHC's physical presence does not guarantee functional access. High population densities in the Central and North zones have led to severe service pressure, while the Southern zone remains hindered by geographic friction and transport costs. Ultimately, the current Ward Health System serves as a rigid administrative barrier to achieving Sustainable Development Goal 3 (SDG 3). To achieve Universal Health Coverage, the state must transition from a model of "territorial equality" to one of Spatial Justice, where healthcare infrastructure is distributed based on human need rather than political boundaries.

Based on the empirical evidence and statistical findings of this study, the following interventions are proposed to address the spatial and economic inequities in Kaduna State's healthcare landscape:

i. The Kaduna State Contributory Health Management Authority (KADCHMA) should provide targeted subsidies for the 87.96% of households living below the poverty line. Prioritizing "equity-based enrollment" in high-density, low-income wards will mitigate the "proximity-poverty paradox" by eliminating the income barrier.

ii. The state must transition from the rigid "one PHC per ward" mandate to Maximum Coverage Location Models (MCLM). New infrastructure and upgrades should be prioritized for the 36 wards identified with "very poor" access, where population-to-facility ratios exceed 1:40,000.

iii. A weighted funding formula should be implemented to ensure that wards with high socioeconomic vulnerability receive higher operational budgets and increased personnel. This is essential to alleviate the service pressure identified by the ANOVA results ($F=18.42$).

iv. To address the physical distance and difficult terrain in the Southern Zone, static public PHCs should be complemented with mobile health units and outreach programs. This hybrid model ensures that geographic friction does not result in healthcare exclusion.

v. A Geospatial Intelligence Unit should be established within the State Primary Health Care Board. This unit would use GIS for real-time monitoring of population-to-facility ratios, allowing for dynamic resource adjustment as demographic shifts occur.

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