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Accessibility of Rural Health Infrastructure Using GIS in Semi-Arid Rajasthan: A Medical Geographical Assessment

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Abstract: ***Rural health accessibility in semi-arid Rajasthan remains a critical concern due to sparse settlements, limited transport connectivity, water scarcity, and the uneven distribution of healthcare infrastructure. This research paper evaluates the geographical accessibility of rural health services spatial analysis in the semi-arid districts of Jaipur, Nagaur, Ajmer, Sikar, and Jhunjhunu. Primary Health Centres, Community Health Centres, Sub-centres, and district hospitals were mapped to analyse spatial distribution, service coverage, and travel-time accessibility. Village-level demographic data and road-network layers were integrated to generate accessibility zones of 5 km, 10 km, and 15 km buffers around health facilities. Results show that although the region has expanded health infrastructure since the National Rural Health Mission, significant disparities persist: many remote villages fall outside the 10 km service zone, particularly in Nagaur and Sikar. The study concludes that assessment provides a robust tool for identifying spatial gaps and can guide location-allocation planning for future facilities. The paper recommends targeted micro-planning, improved rural transport connectivity, mobile medical units, and spatially optimised resource distribution to strengthen rural healthcare accessibility.***

Keywords: Rural health; accessibility; semi-arid Rajasthan; PHC distribution; healthcare infrastructure; spatial analysis; health planning.

1.1 Introduction

Healthcare accessibility is a multidimensional concept involving geographical reach, affordability, availability, and acceptability. In a semi-arid region like Rajasthan, geographical accessibility becomes the most critical determinant because settlements are widely scattered, transportation facilities are inadequate, and climatic conditions intensify the vulnerability of rural populations. According to the Census of India (2011), more than 75% of Rajasthan's population lives in rural areas, and over one-third resides in semi-arid zones. These regions face chronic challenges such as water scarcity, low agricultural productivity, limited economic opportunities, and poor access to essential services, including health care.

Over the past two decades, the Government of India has implemented several programmes, most notably the National Rural Health Mission (2005), aimed at strengthening rural health infrastructure. Rajasthan, being one of the largest states with widely varying physiographic and socio-economic conditions, witnessed significant expansion of PHCs, CHCs, and Sub-centres. Yet several studies indicate persistent disparities in health outcomes such as maternal mortality, infant mortality, respiratory infections, and water-borne diseases in rural areas.

Medical geography, as a discipline, focuses on the spatial dimensions of health and disease. Geographic Information System offers a scientific approach to visualising and analysing spatial inequalities in healthcare distribution, helping planners identify underserved areas and improve service accessibility. This research applies Geographic Information System tools to assess the spatial distribution and accessibility of rural health facilities in the semi-arid districts of Rajasthan.

1.2 Objectives

1. To map the spatial distribution of rural health infrastructure (Sub-centres, PHCs, CHCs, district hospitals) in semi-arid Rajasthan.

2. To analyse accessibility zones of 5 km, 10 km, and 15 km surrounding major healthcare facilities.

3. To identify underserved or poorly served rural villages using GIS-based buffer and network analysis.

4. To compare accessibility patterns among the selected semi-arid districts.

5. To propose strategies for improving rural health accessibility through spatial planning and micro-level interventions.

1.3 Methodology

I. Study Design

A descriptive and spatial analytical research design was adopted. GIS mapping, buffer analysis, and overlay techniques were used to assess accessibility.

II. Data Sources

1. District-wise health infrastructure: Rural health statistics, Ministry of Health and Family Welfare (MoHFW), GoI (2015–2017).

2. Village population data: Census of India, 2011.

3. Road network layers: OpenStreetMap and state road atlas.

4. Administrative boundaries: Survey of India (SOI).

III. Analytical Techniques

1. Geo-coding of health infrastructure.

2. Creation of point layers for Sub-centres, PHCs, CHCs, and hospitals.

3. Generation of buffer zones of 5 km, 10 km, and 15 km.

4. Spatial join of villages falling within and outside service buffers.

5. Accessibility comparison among districts.

6. Location-allocation modelling for identifying optimal sites for new facilities.

1.4 Study Area

Semi-arid Rajasthan covers districts that lie in the transitional zone between arid Thar Desert and sub-humid eastern plains. This study covers:

1. Jaipur, 2. Nagaur, 3. Ajmer, 4. Sikar and 5. Jhunjhunu

Characteristics:

1. Climate: Low rainfall (300–500 mm annually), high evaporation, large diurnal temperature variation.

2. Terrain: Alluvial plains, rocky outcrops, inland drainage.

3. Economy: Agriculture (rain-fed), livestock rearing, rural handicrafts.

4. Settlement pattern: Dispersed rural habitations, small hamlets (dhani system), variable connectivity.

These conditions significantly influence access to healthcare.

1.5 Observations

I. Distribution of Health Facilities

1. Jaipur district shows the densest network of PHCs and CHCs.

2. Nagaur and Sikar have wide inter-facility distances (10–25 km).

3. Ajmer and Jhunjhunu have moderate but uneven distribution.

II. Accessibility Zone Analysis

1. Villages within 5 km of PHCs: ~38%

2. Villages within 10 km: ~62%

3. Villages outside 15 km: ~11% (significant spatial exclusion)

III. District-wise gaps

1. Nagaur: Largest underserved belt, especially in Kuchaman–Didwana area.

2. Sikar: Notable gaps in Fatehpur–Laxmangarh rural belt.

3. Jhunjhunu: Good coverage but poor road connectivity affects actual accessibility.

4. Jaipur: Mostly well-covered except western rural fringes.

5. Ajmer: South-eastern villages remain distant from CHCs.

IV. Road Connectivity

Villages with kutcha roads exhibit significantly higher travel time even if located within buffer zones.

1.6 Discussion

The semi-arid districts of Rajasthan present a challenging environment for rural health access. Despite improvements under the NRHM, spatial inequality remains high. GIS-based analysis reveals:

1. Spatial Inequality

Health centres are concentrated near major roads and market towns, leaving remote hamlets comparatively excluded.

2. Settlement Pattern Influence

The dhani system—small, scattered settlement units—makes it difficult to provide equitable health coverage.

3. Climatic Stress

Semi-arid regions experience heat stress, water scarcity, and high prevalence of vector- and water-borne diseases, but health infrastructure has not expanded in proportion to climatic vulnerability.

4. Transport and Travel Time

Actual accessibility is influenced more by road quality and vehicle availability than straight-line distance.

5. Need for Location-Allocation Planning

Many underserved villages fall between CHCs, indicating the need for new Sub-centres or mobile units.

1.7 Results

1. The GIS analysis demonstrates that 38% villages have immediate access (within 5 km) to a PHC.

2. 62% villages fall within reasonable access (10 km).

3. Approximately 11% villages remain outside the 15 km service zone, indicating poor accessibility.

4. Nagaur and Sikar have the largest accessibility gaps.

5. Jaipur district performs best due to denser infrastructure and improved transport.

6. Location-allocation modelling identifies 17 optimal points for setting up new facilities across the study area.

1.8 Conclusion

Rural health infrastructure in semi-arid Rajasthan shows significant spatial variation. While Jaipur and parts of Jhunjhunu possess a relatively strong healthcare network, Nagaur, Sikar, and Ajmer exhibit major accessibility gaps. Spatial analysis helps identify precise underserved locations and provides a scientific foundation for rational health planning. Addressing geographical inequalities through

targeted interventions can significantly improve rural health outcomes.

1.9 Recommendations

1. Establish PHCs/Sub-centres in identified spatial gap zones (especially Nagaur and Sikar).

2. Deploy Mobile Medical Units (MMUs) to service remote hamlets.

3. Improve rural transport through all-weather roads.

4. Integrate GIS in district-level health planning for continuous monitoring.

5. Strengthen telemedicine services to reduce physical barriers.

6. Recruit more health workers and assign them to underserved areas.

7. Community participation in health awareness and local monitoring.

8. Periodic spatial audits using GPS/GIS for infrastructure evaluation.

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