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Spatial Analysis of Vector-Borne Diseases in Rajasthan: A Study on Malaria, Dengue, and Chikungunya Patterns

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Abstract: ***Vector-borne diseases represent a major public health challenge in Rajasthan, a state characterized by diverse physiographic, climatic, and socio-environmental conditions. This study investigates the spatial distribution, temporal variability, and environmental determinants of Malaria, Dengue, and Chikungunya across districts of Rajasthan using Geographic Information System tools. The research synthesizes epidemiological data, climatic variables, land use patterns, and demographic information from secondary sources before 2018. Through spatial mapping, hotspot analysis, and correlation evaluation, the study identifies high-risk zones in the eastern, southern, and urbanized regions of the state, particularly Jaipur, Alwar, Dausa, Bharatpur, Udaipur, and Kota. Results highlight that waterlogging, urban density, inadequate drainage, and monsoonal humidity are major drivers in Dengue and Chikungunya transmission, while Malaria is strongly influenced by rural water bodies, temperature ranges, and agricultural environments. The study underscores the importance of integrating GIS with public health decision-making for targeted interventions, disease surveillance, and resource allocation. Recommendations include strengthening GIS-based early-warning systems, community-level vector management, and climate-sensitive health planning.***

Keywords: Rajasthan; Vector-borne diseases; Malaria; Dengue; Chikungunya; Spatial epidemiology; Public health geography; Hotspot analysis; Climate–disease interaction.

1.1 Introduction

Vector-borne diseases constitute a crucial component of epidemiological challenges in India, particularly in environmentally diverse states like Rajasthan. Malaria, Dengue, and Chikungunya are among the most persistent and widespread illnesses transmitted primarily through mosquito vectors, namely Anopheles, Aedes aegypti, and Aedes albopictus. In the last several decades, Rajasthan has witnessed fluctuating patterns of disease outbreaks due to factors such as climate variability, rapid urbanization, changes in land use, and inadequate waste management.

GIS has emerged as a powerful tool to understand spatial–temporal disease patterns, analyze environmental determinants, and support decision-making in public health. Methods allow visualizing disease hotspots, understanding transmission corridors, identifying environmental risk variables, and predicting future outbreaks. Although several epidemiological studies have been conducted in Rajasthan before 2018, systematic spatial analysis connecting climate, environment, and disease distribution remained limited.

This research aims to bridge this gap by providing a comprehensive spatial assessment of Malaria, Dengue, and Chikungunya patterns in Rajasthan using geographic, climatic, and demographic variables. The study uses a multidisciplinary approach integrating medical geography, epidemiology, environmental science, and spatial technology.

1.2 Objectives

1. To analyze the spatial–temporal distribution of Malaria, Dengue, and Chikungunya in Rajasthan.

2. To identify district-level hotspots and high-risk zones of vector-borne diseases.

3. To examine the relationship between climatic variables (temperature, rainfall, humidity) and disease incidence.

4. To assess the role of land use, urbanization, and water bodies in influencing disease patterns.

5. To propose strategies for disease surveillance, control, and public-health planning.

1.3 Methodology

This study is based on a integrated secondary data analysis approach. The following methods were applied:

I. Data Sources

1. District-wise disease incidence data (Malaria, Dengue, Chikungunya) from Rajasthan's Medical & Health Department (2018).

2. Climatic data (rainfall, temperature, humidity) from IMD reports.

3. Land use/land cover maps from NRSC.

4. Population density and urbanization data from Census 2011.

5. Administrative boundary shapefiles from Survey of India.

II. Spatial Data Processing

1. All data were georeferenced to WGS 84 coordinate system.

2. Disease incidence was normalized per 1,00,000 population.

3. Hotspot analysis statistics.

4. Interpolation used to generate climatic variability surfaces.

5. Land use and water bodies analyzed using supervised classification.

6. Spatial correlation applied to examine environmental–disease relationships.

III. Analytical Framework

1. Disease mapping for three diseases across 33 districts.

2. Hotspot identification for high and low clusters.

3. Climate–disease correlation analysis.

4. Urban–rural risk pattern assessment.

5. Interpretation using medical geography principles.

1.4 Study Area

Rajasthan, located in northwestern India, is the largest state by area (342,239 sq. km). The state's geography is marked by:

1. Arid and semi-arid zones (Thar Desert)

2. Semi-humid eastern plains

3. Hill ecosystems (Aravalli Range)

4. Irrigated agricultural zones (Indira Gandhi Canal)

5. Urban centres (Jaipur, Jodhpur, Kota, Udaipur)

6. Climatic features relevant to disease transmission include:

7. Temperature ranging from 5°C in winter to 49°C in summer

8. Monsoon rainfall variability (100–600 mm annually)

9. Significant micro-climatic differences

10. High humidity during monsoon and post-monsoon periods

Vector breeding is influenced by water storage habits, stagnant water, poor sanitation, and rapid urbanization, especially in eastern and southern Rajasthan.

1.5 Observations

I. Malaria

1. High incidence reported in tribal and forested districts such as Dungarpur, Banswara, Udaipur, Baran, and Sirohi.

2. Rural ponds, rice fields, open drains, and slow-flowing streams serve as breeding grounds for Anopheles mosquitoes.

3. Incidence peaks during July–September.

II Dengue

Mostly concentrated in urban and peri-urban areas:

1. Jaipur, Kota, Ajmer, Alwar, Bharatpur, Jodhpur.

2. Breeds in artificial containers, overhead tanks, AC trays, tires, and construction sites.

3. Incidence peaks between August–November.

III. Chikungunya

1. Spatially overlaps with Dengue due to similar breeding conditions.

2. Increasing trend observed in Jaipur, Alwar, Bharatpur, Jhunjhunu, and Nagaur before 2018.

3. Relatively lower mortality but high morbidity.

IV. Climate Relationship

1. Temperature between 24–32°C and high humidity favored Dengue and Chikungunya.

2. Malaria prevalence strongly linked with monsoonal rainfall and waterlogging.

3. Heatwaves reduced vector survival in western Rajasthan.

V. Urbanization and Land Use

1. High-density urban pockets had the highest Dengue/Chikungunya cases.

2. Canal-irrigated agricultural areas correlated with Malaria prevalence.

1.6 Discussion

Disease mapping reveals distinct spatial patterns influenced by climatic, environmental, and socio-economic factors.

I. Eastern Rajasthan as a Hotspot

Eastern districts—Jaipur, Alwar, Bharatpur, Dausa, Karauli—showed strong clustering for Dengue and Chikungunya due to:

1. High population density

2. Poor drainage

3. Construction activity

4. Abundant artificial water containers

II. Southern Rajasthan and Malaria

Tribal belts—Banswara, Dungarpur, Udaipur—recorded higher Malaria incidence, supported by:

1. Dense vegetation

2. Rural water reservoirs

3. Limited health infrastructure

4. Seasonal agriculture-related water stagnation

III. Urban vs. Rural Transmission Differences

1. Dengue/Chikungunya: urban.

2. Malaria: rural/tribal.

3. Mixed transmission observed in intermediate towns like Kota and Ajmer.

IV. Climate Sensitivity

1. Higher rainfall and humid conditions directly increased vector breeding.

2. Western Rajasthan's arid regions saw fewer cases except irrigated and urban pockets.

7. Results

I. Three major disease clusters identified:

1. Dengue/Chikungunya: Jaipur–Alwar–Bharatpur belt.

2. Malaria: Udaipur–Banswara–Dungarpur tribal belt.

3. Mixed cluster: Kota–Baran.

II. Environmental correlation:

1. Positive correlation found between rainfall (July–September) and Malaria incidence.

2. Strong correlation between humidity (August–November) and Dengue/Chikungunya.

III. Urbanization as a key risk factor:

High-density cities showed more container-breeding mosquitoes.

IV. Canal irrigation influenced Malaria spread in Ganganagar and Hanumangarh.

V. Hotspot analysis (Gi) confirmed* eastern Rajasthan as a high-risk zone.

8. Conclusion

The spatial dynamics of vector-borne diseases in Rajasthan reveal that climatic variability, land use patterns, and urbanization strongly influence disease transmission. GIS-based analytical methods provide a robust framework for understanding disease ecology and developing location-specific public health interventions. Malaria remains a rural and tribal concern, while Dengue and Chikungunya predominantly affect urban populations. Strengthening disease surveillance, improving environmental sanitation, and integrating GIS tools into public health infrastructure are essential to reduce disease burden.

9. Recommendations

1. Develop a state-wide early warning system for vector-borne diseases.

2. District-level vector mapping to identify micro-hotspots.

3. Strengthening urban sanitation systems, especially waste water and drainage.

4. Community-based vector control programs promoting dry-day practices and container cleaning.

5. Climate-sensitive health planning, integrating IMD predictions with health alerts.

6. Strengthen health facilities in tribal and rural belts prone to Malaria.

7. Promote GIS training for medical and administrative officers.

8. Use satellite-based monitoring for identifying stagnant water and risk zones.

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