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Spatial analysis and efficiency of healthcare delivery system in Meghalaya State, India: A 'Z' Score Approach

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Abstract

The study investigates the spatial distribution, significance, and efficiency of the healthcare delivery system in the northeastern state of Meghalaya, India. Utilising secondary data from the Statistical Handbook of 2022 and analytical techniques including Z-score standardisation and correlation matrix analysis via SPSS, the study highlights disparities in healthcare access and performance across districts. Findings reveal that districts like East Khasi Hills and West Garo Hills, which are better connected and urbanized, demonstrate higher healthcare efficiency, while remote and underdeveloped districts face infrastructural and personnel deficits. The research emphasises the need for decentralization, equitable distribution of healthcare infrastructure, community-level engagement, and integration of modern medical technologies. The study proposes strategic recommendations to strengthen primary health care (PHC) and improve health outcomes, particularly for underserved populations. When it comes to health care efficiency based on Z Score ranking, East Khasi Hills, West Jaintia Hills and West Garo Hills have the highest score in terms of being the most efficient district in health care delivery in Meghalaya state.

Keywords: Healthcare Delivery System; Spatial Distribution; Z-Score Analysis; Primary Health Care (PHC); GIS

1. Introduction

The primary health centre is essential health care made universally accessible to individuals and families in the community using providing essential drugs and medicines [1,2,3]. The community services offered by the PHC are prevention delivery system the and control of endemic diseases and environmental health programmes[4,5,6,7].A health care organisation of people, institutions, and resources that deliver health care services to meet the health needs of target populations[8,9,10]. Effective primary health care relies on seamless coordination between various healthcare providers and services.

Health is influenced by several factors such as adequate food, housing, basic sanitation, healthy lifestyles, protection against environmental hazards and communicable diseases[11,12,13]. The frontiers of health extend beyond the narrow limits of medical care[14,15,16]. Thus, it is said that health care is more than medical care[17,18,19]. Health care embraces a multitude of services provided to individuals or communities by agents of health services or professions, to promote, maintain, monitor or restore health[20,21,22,23].

Health is a common theme in all nations of the world. Health has evolved over the centuries from a concept of concern for an individual to a worldwide social goal and encompasses the whole quality of life [24,25,26]. Health is a state of complete physical, mental, and social well-being and not merely the absence of diseases or infirmity [27,28, 29].

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The main reason for the lack of health consciousness of the people, especially in rural areas is the burden of poverty that has set a major hurdle for getting access to health care[30,31,32,33]. The majority of the population depends on the government-run facilities, which is not very well equipped with all the latest medical facilities, which are at par with the latest technology of medical sciences[34,35,36]. which leads to the un treatability of the more severe illnesses, and this leads to patients being referred to private health care facilities in the city, which leads to their spending, which has greatly led to financial problems for those families[37,38,39,40].

Meghalaya is a state that is situated in a hilly region, the accessibility to health care facilities is very difficult owing to its terrain and the remoteness of some areas. Additionally, the health care facilities are not evenly or equally distributed in all the districts of the state and are concentrated more in the state capital and some major towns, which are the district headquarters of those districts.

Objectives

- The main objectives of this dissertation are given as follows: -
- To analyze the spatial distribution of the health care delivery system in Meghalaya.
- To analyze the significance of the health care delivery system and its efficacy.
- To find out the efficient health care district in Meghalaya.

1.1. Study Area

Meghalaya, 'the Abode of Clouds' is one of the North Eastern states of India. It was carved out of Assam to become an autonomous district on April 2, 1970 and was declared a full fledged state of the Indian Union on January 21, 1972. It lies between latitudes 25°02’ and 26°07’ N and longitudes 89°49’and 92°50’E, with a geographical area of 22,429 sq. Km and an elevation range from 60m to 1961m as (Laitkor Peak at 1961m is the highest) (Fig1). The climate is of monsoon type with distinct warm-wet and cold dry periods. Cherrapunji and Mawsynram, located in the southern part are the rainiest spots of the world. Meghalaya is predominantly a tribal state and inhabited by mainly 3 tribal communities, namely Khasis, Jaintias and Garos who account for 89% of the total population. There are, however other tribes like the Kochs, the Hajong, the Rabhas, the Mikirs and others who are also the aboriginals of the state.

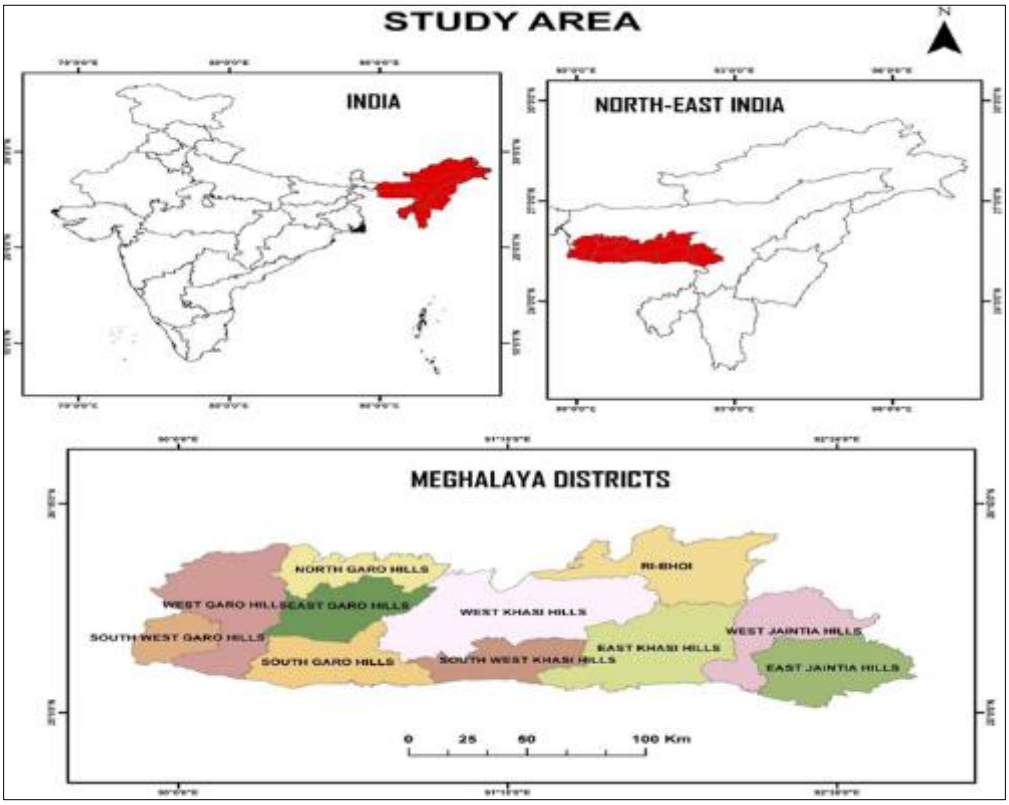

Figure 1 Study Area Map of Meghalaya

2. Data Source and Methodology

2.1. Sources of Data

The data collected for the present study are mainly based on the information provided by the government departments which is through the Statistical Hand Book of 2022 issued by the Directorate of Economics and Statistics Government of Meghalaya, the collected information who are availing these health care services and secondary which are gathered from various sources.

2.2. Secondary Data

The demographic and social variables for Meghalaya were obtained from statistical handbook on Meghalaya for the year 2022 from the Directorate of Economics and Statistics, Shillong. The other statistical data were collected from respective offices. The study area maps and related information were obtained from the statistical handbook for Meghalaya 2022.

2.3. Techniques Used

A Z-Score is a statistical measurement of a score's relationship to the mean in a group of scores. A Z-score of 0 means the score is the same as the mean. A Z-score can be positive or negative, indicating whether it is above or below the mean and by how many standard deviations. A 'Z' score is a statistical measurement of a score's relationship to the mean in a group of scores [41, 42, 43]. A 'Z' score can also be positive or negative indicating whether it is above or below the mean and standard deviation. Z' score can also be explained as in addition of showing a score's relationship to the mean. The 'Z' score shows statistical data set. One real life application of 'Z' score is an usability testing's' score is arrived at by calculating the difference so derived is divided by the standard deviation of the population [44, 45,46].

$$z = \frac{x - \mu}{\sigma}$$

2.4. Tools and Techniques

The relationships and the interdependent nature of different variables are analysed using the correlation matrix, capable of explaining the relationships of one variable with all other variables. Correlation matrix which is derived by using SPSS (Statistical Package for Social science), Standardised score ('Z' Score) techniques are the methods of scale transformation used to analyze the factors of socio-economic and health[47,48,49].

3. Results

The spatial and statistical analysis of the health care delivery system in Meghalaya reveals significant disparities in the distribution and availability of health infrastructure and human resources across the eleven districts of the state. The results derived using Z score analysis (through SPSS 14.0) and mapped using QGIS demonstrate the following key findings: According to Z score analysis, the region may be classified into 4 categories, such as very high representing values of (more than 0.50), High (0- 0.50) moderate (-0.50- 0) and low (less than -0.50). All the maps in this chapter are created by using Z score values and classified spatially according to figures.

3.1. Distribution of Primary Health Centres (PHCs)

The spatial analysis of PHCs highlights that East Khasi Hills district stands out with the highest Z score (2.55), indicating a very high concentration of PHCs (Table 1). This can be attributed to the district's urbanisation, higher population density, and presence of the state capital, Shillong (Fig 2).In contrast, South West Khasi Hills shows a very low Z score (-1.06), reflecting the lowest number of PHCs due to its recent bifurcation from West Khasi Hills and underdeveloped health infrastructure (Fig 3). In contrast, districts with rugged terrain and sparse population like South West Khasi Hills face logistical challenges, resulting in fewer health centres and limited accessibility to healthcare services.

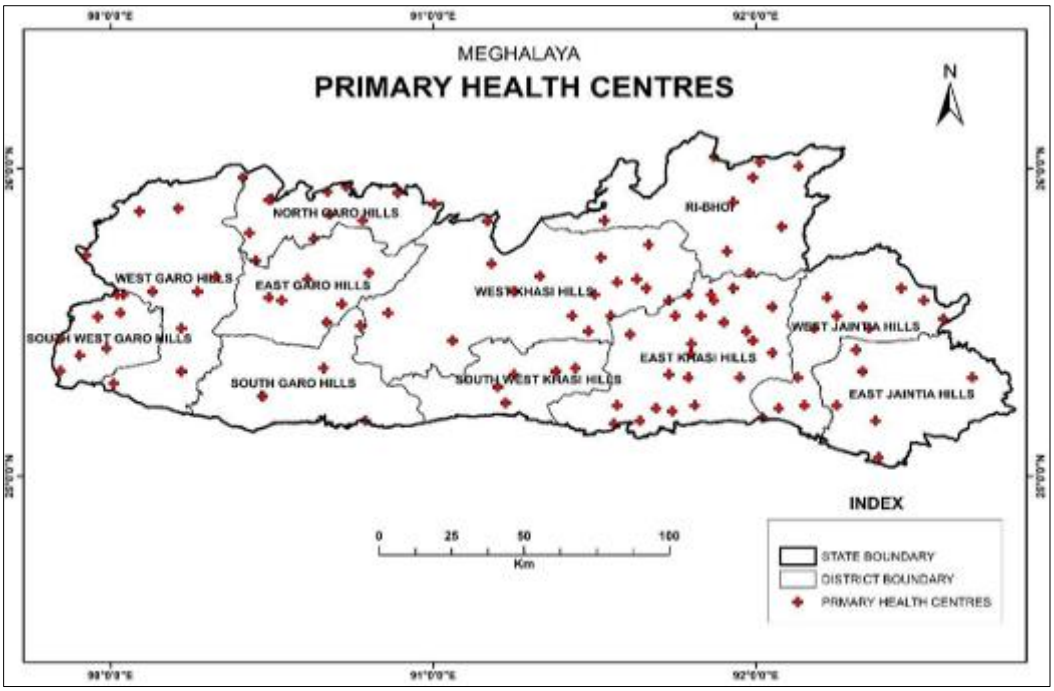

Figure 2 Spatial Distribution of PHCs Meghalaya

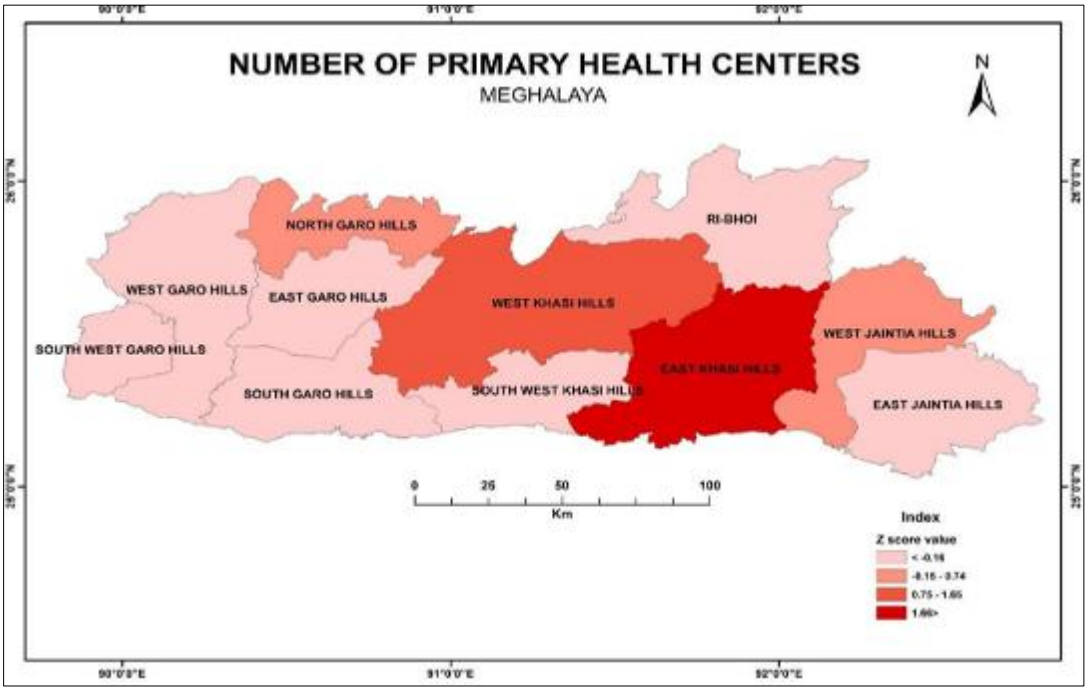

Figure 3 Number of Primary health centre

Table 1 Number of PHCs Meghalaya

District	PHCs	Z Score Value
East Khasi Hills	27	-0.72
West Khasi Hills	5	0.31
South West Khasi Hills	4	-0.38
Eastern West Khasi Hills	11	2.55
Ri Bhoi	9	0.83
West Jaintia Hills	11	-1.06
East Jaintia Hills	6	0.14
West Garo Hills	11	-0.55
South West Garo Hills	9	-0.20
East Garo Hills	8	-0.72
South Garo Hills	6	-0.20
North Garo Hills	9	0.83
TOTAL	116	

3.2. Availability of Doctors

A similar trend is seen in the distribution of doctors. East Khasi Hills again scores the highest (2.42), supported by the presence of specialised medical facilities and higher patient inflow from nearby districts (Table 2). West Garo Hills (1.33) follows due to its regional prominence. East Jaintia Hills (-0.84) has the least number of doctors, reflecting infrastructural challenges and limited health centres (Fig 4).

Table 2 Number of Doctors

Sl No.	Districts	Z Score
1	East Jaintia Hills	-0.84
2	West Jaintia Hills	0.02
3	Ri Bhoi	-0.13
4	East Khasi Hills	2.42
5	West Khasi Hills	-0.06
6	South West Khasi Hills	-0.74
7	North Garo Hills	-0.65
8	East Garo Hills	-0.28
9	West Garo Hills	1.33
10	South Garo Hills	-0.52
11	South West Garo Hills	-0.54

Sources: compiled by author

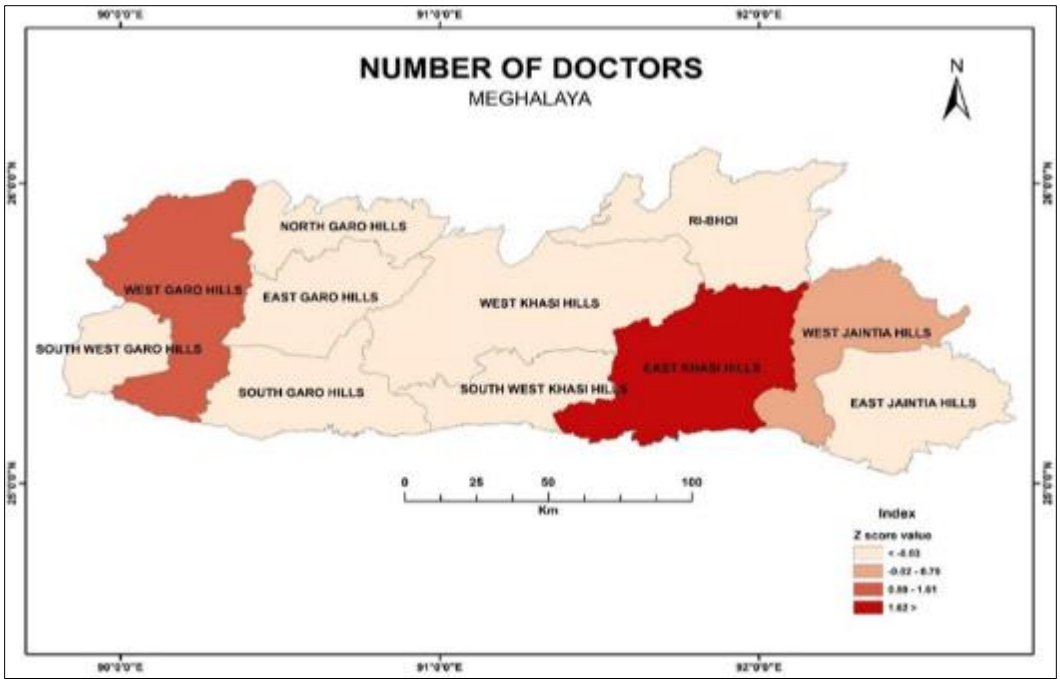

Figure 4 Number of Doctors

3.3. Availability of Pharmacists

The concentration of pharmacists correlates with the number of health centres. East Khasi Hills scores the highest (2.73), indicating an adequate number of pharmacists serving the population. South West Khasi Hills (-0.85) again records the lowest, reinforcing the district's underserved status (Table 3:Fig 5).

Table 3 Number of Pharmacists

Sl No.	Districts	Z Score
1	East Jaintia Hills	-0.58
2	West Jaintia Hills	0.23
3	Ri Bhoi	-0.37
4	East Khasi Hills	2.73
5	West Khasi Hills	0.44
6	South West Khasi Hills	-0.85
7	North Garo Hills	-0.37
8	East Garo Hills	-0.44
9	West Garo Hills	0.37
10	South Garo Hills	-0.58
11	South West Garo Hills	-0.58

Sources: compiled by author

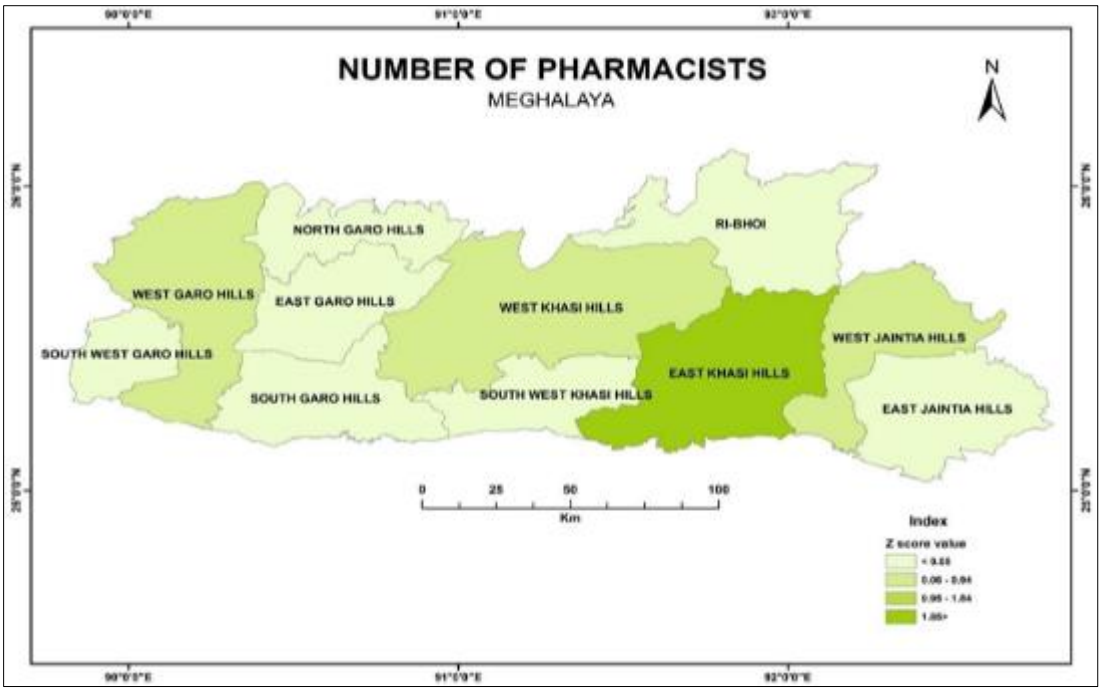

Figure 5 Number of Pharmacists

3.4. Healthcare Efficiency

Efficiency, assessed through multiple indicators (infrastructure, manpower, and accessibility), shows that East Khasi Hills (Z score 119), West Garo Hills (94), and West Jaintia Hills (82) are the most efficient districts. These districts are urbanized hubs and administrative centres with better transportation and healthcare networks (Table 4). Conversely, South West Khasi Hills (24) and South Garo Hills (31) are the least efficient, largely due to rugged terrain, sparse population, and limited healthcare reach. (Fig 6). Factors contributing to this inefficiency include difficult terrain, lower population density, poor road connectivity, and underdeveloped healthcare infrastructure [50,51,52,53]. These districts suffer from delays in emergency medical response, poor immunization outreach, and limited availability of diagnostic services.

3.5. Availability of Medical Manpower

A similar pattern is observed in the distribution of doctors and pharmacists. East Khasi Hills (Z=2.42 for doctors, Z=2.73 for pharmacists) leads due to its extensive healthcare network and the presence of specialist services. The presence of tertiary care institutions and referral centres in Shillong attracts more medical professionals to the region. Conversely, districts like East Jaintia Hills (-0.84 for doctors) and South West Khasi Hills (-0.85 for pharmacists) have significantly fewer medical personnel, resulting in lower service availability and increased patient load in nearby urban centres. The imbalance in the distribution of medical professionals correlates directly with the availability of PHCs. Districts with fewer PHCs also have lower human resource deployment, reflecting a systemic gap in healthcare planning and service delivery [54,55,56].

3.6. Immunization and Family Welfare Services

Immunization coverage is highest in East Khasi Hills and West Khasi Hills, indicating better outreach and public health awareness. Family welfare services also show uneven distribution, with urban districts having better facilities and awareness campaigns.

Table 4 Z score value of Health Care Delivery System in Meghalaya

District	Primary HealthCentre	CommunityHealthCentre	SubCentre	Doctors	Nurses	Pharmacist	LabTechnicians	Vaccinator	ANM	HealthVisitors	GeneralBeds	FullyImmunized	BCGcompleteddoses	TTforpregnantwomen	Measlesvaccine	FamilyWelfareClinics	Rural	Urban	No.ofpatientstreated	Total
WestJaintiaHills	0.31	0.28	0.31	0.02	-0.16	0.23	0.33	0.18	0.26	1.56	-0.04	0.56	0.34	0.26	0.57	0.29	0.31	0.02	0.41	0.41
RiBhoi	-0.38	0.28	-0.42	-0.13	-0.27	-0.37	0.04	-0.76	-0.59	-0.69	-0.19	-0.30	-0.34	-0.11	-0.27	-0.38	-0.38	-0.49	0.73	0.63
EastKhasiHills	2.55	2.31	1.88	2.42	2.90	2.73	2.59	2.64	2.58	2.26	2.77	2.14	2.57	2.32	2.09	2.33	2.22	2.84	2.63	2.63
WestKhasiHills	0.83	-0.23	0.31	-0.06	-0.12	0.44	0.42	0.18	-0.06	-0.35	0.33	0.99	0.29	0.54	1.03	0.32	0.35	0.02	0.08	0.14
SouthWestKhasiHill	-1.06	-0.23	-1.32	-0.74	-0.62	-0.85	-0.99	-0.76	-1.26	-0.69	-0.83	-0.82	-0.73	-0.88	-0.84	-1.12	-1.19	-0.49	-0.64	-0.67
NorthGaroHills	0.14	-0.74	0.49	-0.65	-0.54	-0.37	-0.52	-0.52	0.12	-0.17	-0.68	-0.72	-0.52	-0.55	-0.75	0.18	0.31	-0.49	-0.77	-0.76
EastGaroHills	-0.55	-0.74	-0.60	-0.28	-0.27	-0.44	-0.43	-0.52	-0.34	-0.87	-0.45	-0.74	-0.55	-0.62	-0.74	-0.56	-0.58	-0.49	-0.49	-0.52
WestGaroHills	-0.20	1.29	1.46	1.33	0.36	0.37	0.51	0.53	0.68	-0.17	0.45	0.92	0.86	1.14	0.95	1.03	1.08	0.53	-0.08	0.03
SouthGaroHills	-0.72	-0.74	-0.90	-0.52	-0.38	-0.58	-0.81	-0.05	-0.68	-0.52	-0.49	-0.91	-0.72	-0.84	-0.91	-0.95	-1.02	-0.49	-0.65	-0.67

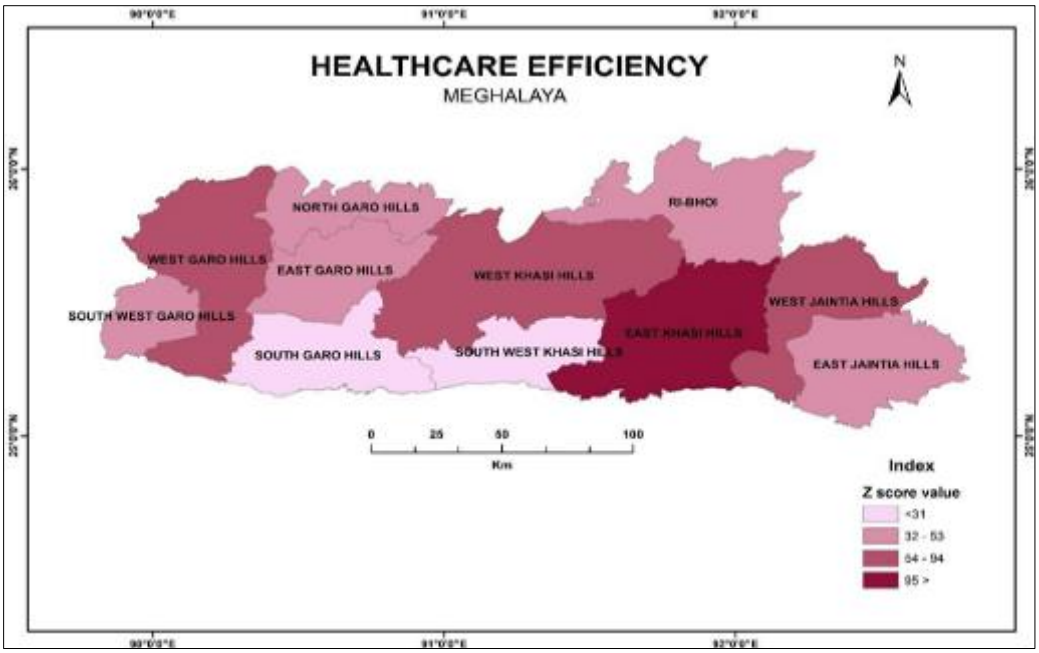

Figure 6 Healthcare Efficiency

3.7. Overall Spatial Pattern

The spatial patterns indicate that districts with better connectivity, higher urbanization, and administrative significance tend to perform better in terms of healthcare delivery. Districts with difficult terrain and rural settlements lag behind in infrastructure and healthcare accessibility.

4. Discussion

The health care delivery system in Meghalaya presents a complex picture of progress and challenges. The spatial analysis using Z scores has revealed substantial disparities in the distribution and accessibility of primary healthcare infrastructure across the eleven districts of the state. The rugged terrain and dispersed rural population play a significant role in shaping the healthcare lands cape. Districts such as East Khasi Hills, West Garo Hills, and West Jaintia Hills consistently perform better in terms of the number of PHCs, availability of doctors, pharmacists, and overall healthcare efficiency. These districts benefit from higher population density, better road connectivity, urbanization, and proximity to administrative centers. East Khasi Hills, in particular, houses the state capital, Shillong, and leads in nearly all healthcare parameters due to its advanced infrastructure and concentration of medical manpower.

In contrast, South West Khasi Hills, South Garo Hills, and East Jaintia Hills reflect lower healthcare indicators. These districts are relatively new or geographically challenged, leading to limited health infrastructure and medical staff. Poor connectivity and lower population density further exacerbate the challenges of providing equitable healthcare services in these regions.

The study highlights that while PHCs are the backbone of rural healthcare, their uneven spatial distribution has led to inefficiencies in healthcare access. The same trend is observed in the availability of doctors and pharmacists, further widening the healthcare gap. Notably, districts with better healthcare infrastructure also report higher immunization coverage and family welfare service delivery, reinforcing the importance of robust local healthcare systems.The efficiency of healthcare delivery, as quantified by Z-score analysis, reveals a direct correlation between the level of urbanization, infrastructure development, and healthcare outcomes. High-performing districts serve as regional healthcare hubs, often catering to surrounding areas due to the lack of facilities elsewhere.

5. Conclusion

The study concludes that Meghalaya's healthcare delivery system, though functioning, is unevenly distributed and influenced by a combination of topographical, demographic, and infrastructural factors. Districts with better connectivity and urban development like East Khasi Hills and West Garo Hills demonstrate higher efficiency and better

access to healthcare services. Conversely, remote districts struggle with inadequate facilities, insufficient health personnel, and limited service delivery. The findings underscore the urgent need for a more balanced distribution of PHCs and healthcare staff, particularly in under-served districts. Investments in road infrastructure, health awareness, and capacity-building of healthcare workers, especially lab technicians and pharmacists, are essential for strengthening the system. To ensure equitable healthcare for all, policies must focus on decentralizing health services, empowering community-level health workers, and integrating modern medical technologies at the primary level. Only through such inclusive and strategic interventions can Meghalaya move towards a more efficient and accessible healthcare system, ultimately improving health outcomes and quality of life for its When it comes to health care efficiency based on Z Score ranking East Khasi Hills, West Jaintia Hills and West Garo Hills has the highest score in terms of being the most efficient district in health care delivery because it hoses the state capital which covers more of an urban area whereby at the same time have a high population and also have better developed health care infrastructure that can cater to needs of the people.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Saravanabavan, V., Balaji, D., & Preethi, S. (2019). Identification of dengue risk zone: A geo-medical study on Madurai city. Geo Journal, 84, 1073-1087.

[2] Balaji, D., Saravanabavan, V., &Katturajan, K. (2024). Geo-modeling approach of determinants of Chikungunya and its spatial distribution pattern in Madurai city, Tamil Nadu,India. GeoJournal, 89(3), 109.

[3] Vinothini, C., Saravanabavan, V., &Suja Rose, R. S. (2024). Travel patterns of adult patients to primary health centers in Madurai district: A public health perspective. International Journal of Science and Research Archive, 13(1), 141-149. DOI: https://doi.org/10.30574/ijsra.2024.13.1.1605

[4] Fleury, M.-J. (2006). Integrated service networks: The Quebec case. Health Services Management Research, 19(3), 153–165. https://doi.org/10.1258/095148406777888214

[5] Saravanabavan, V., Reejo, R. J., Neethidevi, A., & Jayashree, R. (2006). Travel and health care utilization pattern of patients in Vadippati panchayat union: A micro level study using GIS. Journal of Deccan Geographer, 44(2), 97-108.

[6] Vinothini, C., & Saravanabavan, V. (2022). Spatial Distribution of Emerging Diseases in Madurai District: A Geo Medical Study. International Journal of Innovative Science and Research Technology, 7(6), 2456-2165.

[7] Lyngdoh, M. (2022). Traditional healing practices in Meghalaya: Bridging modern and indigenous systems. Indian Journal of Traditional Knowledge, 21(1), 123–130.

[8] Saravanabavan, V., Reshma, C. U., & Preethi, S. (2021). Determinants of reproductive health in working women in Thrissur district, Kerala. GeoJournal, 86, 239-253.

[9] Saravanabavan, V., Aneesh, P., Babu, H. M., & D Harieswari, M. (2021). Patient's perception and level of primary health care utilization in east block of Madurai North taluk: A geo-health study. International Journal of Geography, Geology and Environment, 3(1), 34-41.

[10] Vinothini, C., Suja Rose, R. S., & Saravanabavan, V. (2024). Assessment of primary health care accessibility and patients' perception in Madurai district: a geo-medical study. GeoJournal, 89(5), 211.https://doi.org/10.1007/s10708-024-11208-1

[11] Umasankar, R. Vijaya, V.Saravanabavan (2024) Geospatial Analysis of Health Care Resource Allocation in Karur District: Insights From GIS.Shodhkosh: Journal of Visual and Performing Arts vol.5 No.1 .DOI: https://doi.org/10.29121/shodhkosh.v5.i1.2024.2040

[12] Saravanabavan, V., Lekha, C. A., Aparna, T., Nisha, R. R., Balaji, K. K., & Kanna, S. V. (2021). Spatio-temporal variation of dengue in Kozhikode District, Kerala: A medico geographical study. International Journal of Mosquito Research, 8(1 Part B), 130-140.

[13] Rahamath Nisha, R., Saravanabavan, V., & Sureshkumar, R. (2020). Emerging COVID-19 epidemiology in Tamil Nadu India using GIS. International Journal of Contemporary Medical Research, 7(8), H10-H17.

[14] Tiwari, P. (2018). Digitalisation and occupational stress among healthcare workers in India. Indian Journal of Occupational and Environmental Medicine, 22(1), 12–16. https://doi.org/10.4103/ijoem.IJOEM_137_1

[15] Saravanabavan, V., & Shanmugaratnam, S. (1997). Identification of Health Care Delivery System for Paucibacillary Leprosy in Tannilnadu. Geographical Review of India Calcutta, 3(59), 216-24.

[16] Vinothini, C., Saravanabavan, V., &Emayavaramban, V. (2022). Location Accessibility of PHC and Health care travel performance in Madurai District. International Journal of Innovative Science and Research Technology. Volume 7, Issue 12, December – 2022 ISSN, (2456-2165)

[17] Saravanabavan, V. (2013). Patients' perception and travel behavior pattern in primary health care center in Haripad block-A micro-Geo-medical study. Journal of Language in India, 13(4), 194-207.

[18] Saravanabavan, V. (2011). GIS analysis of pedestrian problem and spatial risk areas for each buffer zone in uraban cities a case study of Madurai city in Tamlnadu, India , Proceedings of the 1st International Symposium 2011 on Post-War Economic Development through Science, Technology and Management, p. 149 , South Eastern University of Sri Lanka, . http://ir.lib.seu.ac.lk/handle/123456789/862

[19] Mamtani, R., Stern, P., Dawood, I., Cheema, S., & Al-Kuwari, M. (2011). Exposure to toxic chemicals: A health and environmental risk for women and children. Journal of Environmental and Public Health, 2011, 1–5. https://doi.org/10.1155/2011/321643

[20] Lori engiaipi., Saravanabavan, V., & Vinothini, C. (2025). Gender-wise travel pattern and utilization of primary health centers of Karbi Anglong district, Assam. International Journal of Science and Research Archive 14 (03),1320-1330

[21] Saravanabavan, V., &Shanmuganandan, S. (1998). Leprosy and Multidrug therapy in Tamil Nadu, India: A Factor Analysis. The Indian Geographical Journal, 73(1), 41-50.

[22] Saravanabavan, V. (1996). Bicycles and health-a geo medical study of Madurai city. In Velo Australis and Velo-City'96, International Bicycle Conference, 1996, Fremantle, Western Australia.

[23] Minkman, M. M. N. (2012). Developing integrated care: Towards a development model for integrated care. International Journal of Integrated Care, 12, e197. https://doi.org/10.5334/ijic.843

[24] Vinothini C, Suja Rose R.S, Saravanabavan V.(2025) Patient's Satisfaction with Primary Healthcare Services and Its Link to Socio-Economic Conditions in Madurai District. International Journal of Scientific Research and Engineering Development ,8(2) pp 248-253

[25] Saravanabavan, V., Eswari, S., Vimala Vinnarasi, J., Ganesan, J., & Sudharsan, R. (2020). Spatial temporal variation of leptospirosis disease in Madurai city–Medico geographical analysis. International Journal of Geography, Geology and Environment, 2(1), 21-7.

[26] Saravanabavan, V., Emayavaramban, V., Thangamani, V., Manonmani, I. K., Rose, R. S., Balaji, D., ... & Vinothini, C. (2023). Spatial variation of covid-19 morbidity status and identification of risk zone in Tamil Nadu (India) during first wave. GeoJournal, 88(2), 1341-1354.

[27] Muldoon, L. K., Hogg, W. E., & Levitt, M. (2006). Primary care (PC) and primary health care (PHC): What is the difference? Canadian Journal of Public Health, 97(5), 409–411. https://doi.org/10.1007/BF03405306

[28] Saravanabavan, V., & Abeesh, P. (2020). Environmental health status of fishermen in Mahe district. International Journal of Geography, Geology and Environment, 2(2), 95-102.

[29] Saravanabavan, V., Vinothini, C., Balaji, D., Alok, M., Arya, M., & Athira, R. (2022). Geo-spatial approach on COVID-19 mortality in Tamil Nadu. International Journal of Geography, Geology and Environment, 4(1), 123-131.

[30] Vinothini C, R.S Suja Rose, V. Saravanabavan (2024) Spatial Distribution and Female travel behaviour: Enhancing primary health care services in Madurai District. International Journal of Engineering applied Sciences and Technology . Vol 9, Issue 05, Issn No. 2455-2143, pp 193-199.

[31] Saravanabavan, V., Sudharsan, R., Balaji, D., &Rahamath Nisha, R. (2014). Patient's perception and epidemiological characteristics of dengue in Madurai city-using factor analysis. International Journal of Mosquito Research, 1(2), 18-24.

[32] Saravanabavan, V., Balaji, D., Reshma, C. U., Sheheersha, S. K., Sudharsan, R., Vimala Vinnarasi, J., ... & Balasubramani, K. (2021). Urban disease ecology and its spatial variation of Chikungunya in Madurai City, Tamilnadu, India: a geo-medical study. GeoJournal, 86, 2335-2350.

[33] Saravanabavan, V. (2013)GIS Approach on Health Care System and Patient's Perception of Primary Health Care Centres- Micro Level Study. Health and Medical Geography Highlights of Research , Training and Practice ,XVth International Medical Geography Symposium , Department of Geography, Michigan State university, Michigan , United States, July 7-12,2013,152-53.

[34] Saravanabavan, V., Balaji, D., Rahamath, N. R., Preethi, S., & Vadivel, S. (2020). Geo-ecological association of dengue disease in Madurai city-using multivariate analysis.

[35] Saravanabavan, V. (1997). Geo-Medical analysis of Multibacillary Leprosy in Tamil Nadu. The Deccan Geographer, 35(2), 179-189.

[36] Saravanabavan, V., Vinothini, C., & Rose, R. S. (2023). Spatial distribution of primary health care centres and socioeconomic conditions of patients in Madurai district. International Journal of Geography, Geology and Environment, 5(2), 192-198.

[37] Sudharsan, R., & Saravanabavan, V. (2019). Availability and Utilization of Primary Healthcare Centre in Thanjavur District, Tamilnadu. International Journal of Scientific Research in Science and Technology, 6(4), 288-297.

[38] Saravanabavan, V. (2000). An analysis of pattern of leprosy and regional classification of Health Care service in Tamilnadu. Geography Review of India, 62(4), 379-386.

[39] Saravanabavan, V., & Shanmuganandan, S. (1996). Impact of MDT on changing scenario of Leprosy in Tamil Nadu. The Journal of Region, Health and Health Care, 1(2), 19-27.

[40] Vinothini, C., Saravanabavan, V., Suja Rose, R. S.. (2025). Travel Behaviour of Child Patients and Health Care Accessibility of PHC in Madurai District, Tamilnadu. International Research Journal of Education and Technology , 7 (02) , pp283-295

[41] Saravanabavan, V., Keerthi, S. P., Anupama, A., & Vinothini, C. (2019). Psycho-social characteristics of mental disorder patients in Thiruvananthapuram District: A geo-medical study. International Journal of Geography, Geology and Environment, 1(2), 08-16.

[42] Saravanabavan, V., Balaji, D., & Sudharsan, R. (2014). A Geo-Medical Analysis of Chikungunya and Patients Environmental Perception in Madurai City. Journal of JAC Journal of Science, Humanities, and Management, 1(2), 111-120.

[43] Radhakrishnan, R., & Vaithialingam, S. (2023). Exploring the Suitability of Groundwater for Domestic Water Quality and Irrigation Purposes in Dindigul District, Tamil Nadu. In Surface and Groundwater Resources Development and Management in Semi-arid Region: Strategies and Solutions for Sustainable Water Management (pp. 253-277). Cham: Springer International Publishing.

[44] Saravanabavan, V., Vinothini, C., &SujaRose, R. S. (2024). Transport accessibility and efficiency of PHC location in Kanyakumari district, Tamil Nadu. International Journal of Science and Research Archive, 11(2), 1342-1351. DOI: https://doi.org/10.30574/ijsra.2024.11.2.0605

[45] Saravanabavan, V. (1996). Bicycles and health-a geo medical study of Madurai city. In Velo Australis and Velo-City'96, International Bicycle Conference, 1996, Fremantle, Western Australia.

[46] Sheheersha, S. K., & Saravanabavan, V. (2015). An analysis of the role of Sunayanam mobile ophthalmology unit for preventing blindness among rural poor in Thiruvanthapuram district. Geospatial Technologies for Resource Evaluation and Management, 412-414.

[47] Saravanabavan, V., &Shanmuganandan, S. (1994). Geo-Medical analysis of Leprosy patients in Tamilnadu. The Indian Geographical Journal, 69(2), 135-139.

[48] Saravanabavan, V., &Shanmuganandan, S. (1996). Pattern of leprosy treatment and health care situation in Tamil Nadu. Annals of the National Association of Geographers, India, 16(2), 25-35.

[49] Nongrum, I. (2010). Indigenous medicine and rural healthcare in Meghalaya. North Eastern Geographer, 37(1-2), 25–32.

[50] Saravanabavan, V,,Khakchang Debbarma, & Vinothini, C. (2025)Primary Health Care Access and Socio-Economic Conditions of the Patients in Sepahijala District, Tripura. International Journal of Science and Research Archive.Vol 6, No 1, pp 295-305.

[51] Saravanabavan, V., Nokimte N Sangma & Vinothini, C.(2024) Spatial Distribution and Pattern of Location in Primary Health Centers in West Garo Hills District, Meghalaya. International Journal of Research Publication and Reviews. Vol 5, no 11, pp 694-701

[52] Vinothini, C., Suja Rose, R. S., & Saravanabavan, V. (2024). Geospatial Analysis of Communicable Diseases in Madurai District. International Journal of Humanities Social Science, and Management. Vol 4, issue 3, May-June 2024, pp 1145-1153

[53] Saravanabavan, V., Vinothini, C., &Suja Rose, R. S. (2023). Spatial distribution of primary health care centre and socio-economic conditions of patients in Madurai district. International Journal of Geography, Geology and Environment, 5(2), 192-198.

[54] Vinothini C, R.S. Suja Rose, V. Saravanabavan (2024) Demographic and Socio-economic Conditions of Patients of th54.e Primary Health Care Centers in Madurai District, Tamilnadu, India. Indian Journal of Spatial Science 15 (4), 50-55

[55] Nolte, E., & McKee, M. (2008). Caring for people with chronic conditions: A health system perspective. WHO Regional Office Europe.

[56] Thompson, C., Fahimi, S., & Keene, D. (2016). Integrated care models: An overview. Journal of Integrated Care, 24(1), 2–11. https://doi.org/10.1108/JICA-12-2015-0044