

Spatial Mapping of Women's Cancer Case Distribution Using Hospital-Based Cancer Registry Data in Mysuru District, Karnataka: A Feasibility Study

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ABSTRACT

Background: Cancer remains a leading cause of premature mortality among women in India, with wide disparities in access to care and staging at diagnosis. Hospital-Based Cancer Registries (HBCRs) provide clinical insights into cancer case profiles among patients attending tertiary institutions. Integrating Geographic Information System (GIS) with HBCR data offers a novel opportunity to visualize cancer case distributions within hospital catchment areas. The objective was to evaluate the feasibility of integrating GIS with HBCR data to map women's cancer distribution and staging in Mysuru District, Karnataka.

Methodology: A retrospective descriptive study was conducted using HBCR data from January 2019 to December 2022. Confirmed cancer cases among women with valid addresses were included. Sociodemographic and clinical data were analyzed using SPSS. Geographic coordinates were geocoded using Google Earth Pro and mapped using ArcGIS to visualize spatial patterns.

Results: Most cases occurred among middle-aged women, with breast, gynecological, and gastrointestinal cancers being predominant. Over two-thirds of cases were diagnosed at early stages. Spatial mapping revealed clustering of cases near urban centers, while brain and CNS cancers showed a higher proportion of late-stage presentation in rural areas.

Conclusion: Integrating GIS with HBCR data is a feasible method for visualizing cancer patterns and staging. This approach can support institutional planning, though findings are not population-representative.

Keywords: Cancer, Hospital-Based Cancer Registry, Women's Health, GIS, Spatial Mapping, Cancer Staging, Karnataka, India

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INTRODUCTION

Cancer stands as a formidable global health challenge, ranking either first or second among the leading causes of death before the age of 70 in 91 out of 172 countries worldwide.¹ In India, approximately 1.32 million cases were reported in 2020, women bear a significant share of this burden, experiencing a greater impact than men.² The most commonly encountered cancers among women include breast cancer, colorectal cancer, endometrial cancer, lung cancer, cervical cancer, skin cancer, and ovarian cancer.³ Effectively addressing this burden is not only vital for health but also imperative for confronting gender inequalities and recognizing the societal roles of women.⁴

Understanding the nature of these cancers is crucial for implementing preventive measures and early detection strategies, offering substantial improvements in survival rates and reducing the overall disease burden. Cancer surveillance, an integral part of prevention and control efforts, requires an assessment of distinct social, economic, geographic, and cultural factors influencing late diagnosis and suboptimal treatment outcomes. This localized evidence is essential for the effective implementation of national cancer control programs.⁵ These factors, specific to context (e.g., country, region) and tumor-specific, encompass elements like access to care, quality of care, coordination across healthcare sectors, education and training, and intricate personal and community relationships.⁶

While Population-Based Cancer Registries (PBCRs) provide incidence and prevalence estimates for defined population, Hospital-Based Cancer Registries (HBCRs) complement this by offering case-level information on treatment patterns and cancer profiles among hospital attendees. Although HBCRs are not designed to capture population-level burden, they offer meaningful insights into the clinical and geographic catchment of cancer care services particularly within tertiary referral settings. Hospital-based cancer registries are a key tool in this approach and play a crucial role in cancer prevention and control by generating systematic and timely information on new cases of cancer, enabling health system preparedness and framing of programs and policies.⁷

In India, progress in cancer care is evident in well-equipped Tertiary Cancer Centres and trained oncologists in urban areas. However, this progress is not uniform across rural areas, where the incidence of cancer is nearly half that of urban areas, yet the mortality rates are twice as high. With 70% of cancer deaths in India occurring in rural areas, there is a pressing need for change.⁸ Cancer screening emerges as a crucial strategy, not only for medical benefits but also for overall well-being, contributing to cost reduction and enabling timely interventions.

Cancer control can be achieved by providing information to the general population on trends in the oc-

currence, profile, and distribution of cancer cases. Medical geography's practical use in clinical decision support systems and geo-surveillance initiatives is evident. Professionals and analysts in healthcare require enhanced tools for scrutinizing health-related data. The advanced spatial visualization technique offers a competitive edge by anticipating and forecasting diverse associations among geographic elements and endemicity, a feat not easily achievable with conventional statistical analysis.⁹

Since the inception of the National Cancer Registry Programme (NCRP) in 1982, India has diligently collected data on cancer incidence and mortality. While significant progress has been made in utilizing this data to formulate cancer control programs and policies, there exists untapped potential to further enhance its utility and impact through the integration of Geographic Information System (GIS) tools. Despite having access to public data from the cancer registry, an interactive dashboard illustrating cancer spatial patterns is notably absent on any Indian government website.¹⁰

Geographic Information System (GIS) plays a pivotal role in understanding cancers influenced by environmental factors, socioeconomic conditions, and resource access. As part of spatial data infrastructure, GIS facilitates the collection, storage, verification, and presentation of location-associated data. By correlating seemingly disparate data, GIS aids in gaining enhanced insights into spatial patterns and connections.¹¹ Spatial analysis is crucial for cancer research, especially when it comes to gaining insights into regional distribution, clustering, risk factors, and disparities. Incorporating spatial techniques enables a nuanced understanding of the intricate interactions between cancer and its environmental, social, and geographic determinants. This knowledge is essential for developing effective strategies for cancer prevention, early detection, and treatment.¹²

Mysuru District was chosen for this study due to its established tertiary cancer care facilities, robust HBCR database, and diverse mix of urban and rural populations within its referral network. This feasibility study explores the integration of GIS with HBCR data to visualize and analyze the spatial distribution of women's cancers reported to a tertiary care hospital in Mysuru District, Karnataka, between 2019 and 2022. Specifically, the study aims to:

- (i) characterize the demographic and clinical profiles of cancer cases among women,
- (ii) map the spatial distribution of reported cancer types and stages across taluks, and
- (iii) assess geographic trends in case clustering that may guide further research or institutional outreach strategies. By demonstrating the utility and limitations of GIS for hospital-level cancer mapping, this study provides a foundation for future spatial approaches to health service planning and cancer care delivery in similar settings.

METHODOLOGY

Study setting, Study Design and Data collection:

Mysuru District, with an estimated population of approximately 3.0 million as per the 2011 Census, has a population density of ~476 persons per km², a sex ratio of about 985 females per 1000 males, and a literacy rate of around 72.8%. Among this population, roughly 41.5% resides in urban areas, while 58.5% live in rural areas. Moreover, population-based cancer registry data estimated that, in 2021, Mysuru accounted for approximately 4.8% of the annual cancer incidence in Karnataka, with Karnataka reporting roughly 87,300 new cases that year. This implies a substantial cancer burden within the district, which our institutional HBCR captures in a subset of cases, offering localized insights into case distribution.¹³

This study employed a retrospective descriptive design to assess the feasibility of integrating Geographic Information System (GIS) tools with Hospital-Based Cancer Registry (HBCR) data for mapping the spatial distribution of women's cancer cases. The study was conducted at a tertiary care teaching hospital in Mysuru District, Karnataka, India. The hospital maintains an HBCR under the framework of the National Cancer Registry Programme (NCRP) supported by the Indian Council of Medical Research (ICMR). The registry systematically collects patient-level cancer data for clinical, administrative, and research purposes.

The study covered a four-year period from January 2019 to December 2022. The study population comprised women diagnosed with cancer and registered in the HBCR during this period. The inclusion criteria were: (i) women of any age group diagnosed with cancer, (ii) cases with histopathological, cytological, or hematological confirmation, and (iii) availability of a complete residential address with a valid postal PIN code within the 36 taluks of southern Karnataka. Cases were excluded if they lacked sufficient diagnostic confirmation, a valid PIN code, or if their residence was located outside the predefined study area.

Out of 1,898 registered cases, 303 women's cancer cases met the eligibility criteria and were included for spatial analysis.

Data were extracted from the institutional HBCR database, which includes patient demographic, clinical, and treatment-related variables. At the time of registration, each patient is assigned a unique identifier, and standardized data are recorded including name, age, sex, contact information, and full residential address.

The clinical variables collected for this study includes Year of diagnosis, Primary site of cancer, coded according to ICD-10 guidelines, Stage at diagnosis Method of diagnosis (e.g., histopathology, imaging, cytology), Treatment modality (surgery, chemotherapy, radiation, or combinations), & Treatment intent (curative or palliative).

The sociodemographic variables include Age at diagnosis, Marital status, Religion, & Place of residence (urban or rural, based on government classification).

Cancer Types and Classification: The study analyzed all cancer types reported in women during the study period. The most common categories included breast, gynecological (e.g., cervical, ovarian, endometrial), and gastrointestinal cancers, followed by head and neck, respiratory, brain and CNS, lymphoid and hematopoietic malignancies. Cancer types were further grouped by anatomical system for reporting purposes.

Geospatial Framework and Unit of Analysis: Residential addresses were cross-verified using postal PIN codes and manually geocoded in Google Earth Pro. Cases with incomplete, missing, or inconsistent PIN codes were excluded to maintain spatial accuracy. Only records with valid and verifiable PIN codes within the 36 taluks of Mysuru, Mandya, and Chamarajanagar districts were retained. The geocoded addresses were subsequently linked to the corresponding administrative boundaries, with the taluk serving as the geospatial unit of analysis.

Administrative boundary layers for districts and taluks were downloaded from the Karnataka Geographic Information System (KGIS) portal. These shapefiles were used as base maps in GIS analysis.

Ethical Approval: The study protocol was reviewed and approved by the Institutional Ethics Committee of JSS Medical College, Mysuru (Ref: JSS/MC/PG/104/2022-23). As this was a retrospective study utilizing de-identified secondary data, the need for informed consent was waived. The study adhered to the principles of the declaration of Helsinki.

To ensure patient confidentiality, all personal identifiers (such as name, contact information, and exact household address) were removed prior to analysis. Only anonymized datasets containing PIN codes were used for geocoding and mapping.

Statistical Analysis: Data cleaning and tabulation were performed in Microsoft Excel. Statistical analyses were conducted using IBM SPSS Statistics version 22.0 (licensed to JSS AHER). Descriptive statistics were used to summarize categorical variables such as age group, cancer type, staging, and diagnostic modality. Results were presented in the form of frequencies and percentages. While urban-rural differences and stage-wise distributions were represented visually in the figures, no inferential statistical tests (e.g., chi-square) were performed, as the primary objective of this feasibility study was to demonstrate the integration of GIS with HBCR data and provide descriptive insights rather than test statistical associations.

GIS Mapping and Visualization: Spatial analysis was performed using ArcGIS version 10.2 (licences to JSS AHER). The cleaned patient dataset was converted into a CSV file containing geocoded coordinates, and imported into ArcGIS to create Point Fea-

ture Layers for each case. These were overlaid on taluk boundary maps to visualize the spatial distribution of cases by cancer type and stage.

The GIS analysis was descriptive in nature. No spatial statistical tests (e.g., cluster detection or autocorrelation analyses) were performed, as the primary objective was to assess the feasibility of integrating GIS with HBCR data for institutional-level visualization and planning. The resulting maps highlight spatial trends in the distribution of hospital-reported cancer cases, but do not infer population-level incidence or risk patterns.

The choice of IBM SPSS Statistics 22.0 and ArcGIS 10.2 was based on their institutional availability at JSS AHER and their suitability for conducting robust statistical analyses and advanced spatial mapping.

RESULTS

Table 1 represents the sociodemographic characters of the study subjects. Among the 303 Women cancer cases, 134 (44.2%) belonged to the age group of 40-59 years, with only 4 (1.3%) of the Women cancer patients in the age group of 0-19 years.

Table 1: Characteristics of the study subjects (n=303)

Variable	No. of Female (%)
Age group (in years)	
0-19	4 (1.3)
20-39	33 (10.9)
40-59	134 (44.2)
≥60	132 (43.6)
Marital status	
Married	227 (74.9)
Unmarried	16 (5.3)
Separated/Widowed	54 (17.9)
Unknown	6 (2)
Religion	
Hindu	285 (94.1)
Muslim	14 (4.6)
Christian	4 (1.3)
Residence	
Rural	174 (57.4)
Urban	129 (42.6)
Year of Diagnosis	
2019	94 (31)
2020	58 (19.1)
2021	68 (22.4)
2022	83 (27.4)
Method of Diagnosis	
X-ray/ Imaging techniques	154 (50.8)
Microscopic	149 (49.2)
Treatment received	
S+R+C	211 (69.6)
S+C	53 (17.5)
R+C	17 (5.6)
S+R	15 (5)
S	7 (2.3)
Intention to treat RI	
Curative/Radical	240 (79.2)
Palliative	63 (20.8)

The majority of the subjects, 227 (74.9%), are married. The majority of the study subjects follow the Hindu religion, comprising 285 (94.1%), and 174 (57.4%) of Women cancer patients are from rural areas. The majority, 94 (31%), of the study participants were diagnosed in the year 2019, with only 58 (19.1%) diagnosed in 2020. Half, 154 (50.8%), of the study participants were diagnosed using X-ray or imaging techniques, while the other half, 149 (49.2%), were diagnosed using microscopic methods. More than half, 211 (69.6%), of the study participants received C+S+R treatment. The majority, 240 (79.2%), of the study subjects received curative or radical treatment for RI.

Figure 2 presents the spatial distribution of female cancer cases by cancer type and highlights the predominance of breast cancer in Mysuru taluks. Among the 303 study subjects, the three most prevalent cancer types in the study are Breast cancer (26.7%), Gynecological cancer (22.8%), and Gastrointestinal cancer (17.2%). The majority of cases (52.5%) were reported from taluks in Mysuru, followed by 20.4% from Mandya, and 13.2% from taluks in Chamara-janagar districts. Notably, the top three cancers are reported prominently in the taluks of Mysuru, Mandya, and Chamara-janagar districts.

Figure 3, represents the Urban Rural Disparities in cancer types among Females. In this study, a higher number of cancer cases were reported from rural areas compared to urban areas. Among 303 Women cancer cases, Gynecological (63.8%), Gastrointestinal (61.5%), head & neck (60%), bone & connective tissue (60%), respiratory (61.5%), lymph nodes (66.7%), blood (66.7%), and skin (66.7%) cancer cases are reported from rural areas. Interestingly 80% of brain & CNS cancer cases were reported in rural areas. Around 56% of Breast cancer and 55.5% of renal cancer cases are reported from urban areas.

Figure 4, represents the Spatial distribution of stages of cancer in females. The majority of cases (39.3%) fall into Stage 2, followed by 32.7% in Stage 1. Stage 4 represents 21.1% of cases, while only 6.9% are reported in Stage 3. Notably, approximately 48.7% of Stage 2 cancer cases are reported from taluks in Mysuru. Additionally, more than half (55.6%) of Stage 1 cancer cases are reported from taluks in Mysuru. Furthermore, around 48.4% of Stage 4 cases are from taluks in Mysuru, and more than half (66.7%) of Stage 3 cancer cases originate from taluks in Mysuru.

Figure 5, represents the Women's cancer types across different stages of cancer. More than 70% of the Women's cancer cases are reported at stage 1 & stage 2. Notably, 54% of respiratory cancer is reported at stage 1 followed by 83.3% of skin cancer is reported at stage 2. Lymph node cancer, 16.7% reported at stage 3. Brain and CNS cancer, 40% reported at stage 4. Blood cancer is not reported at stage 3 and stage 4. Skin cancer is reported at stage 2 and stage 3.

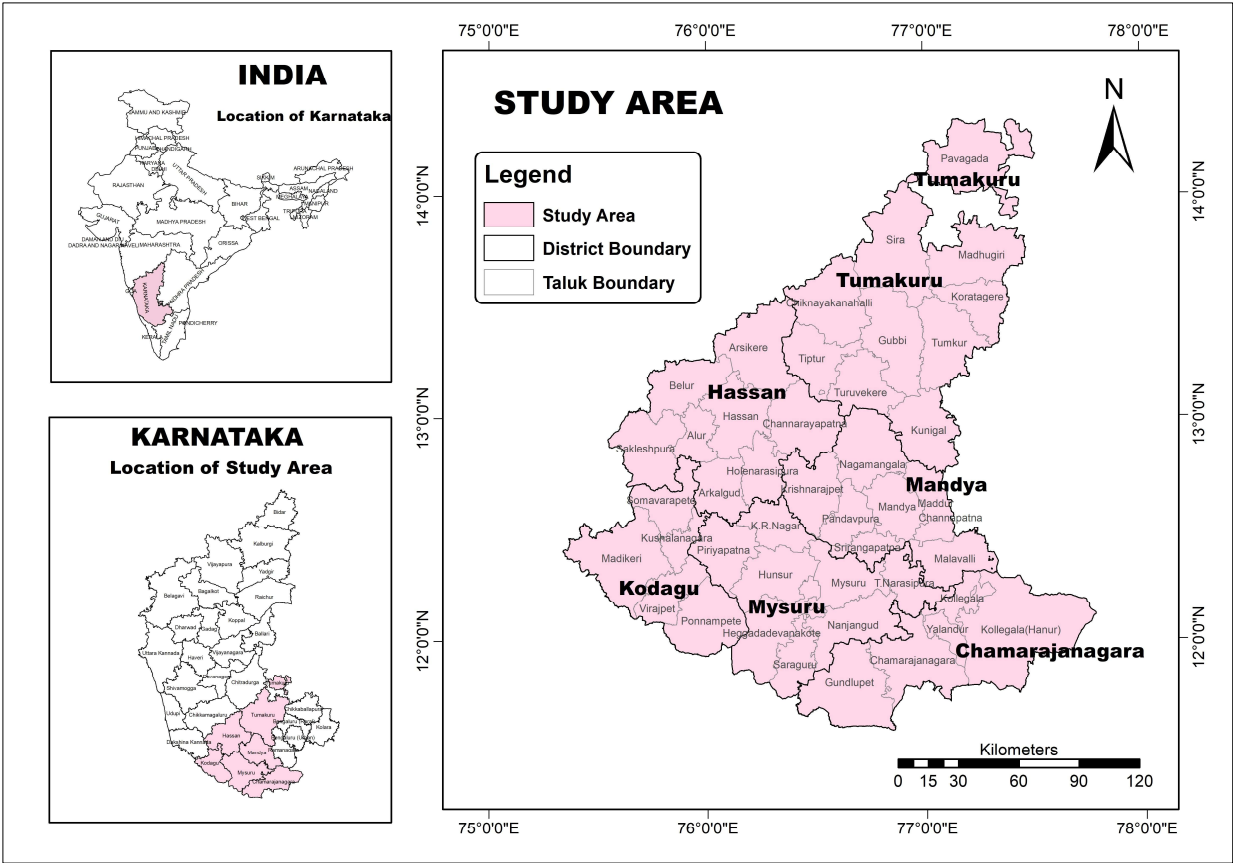


Figure 1: Study Area

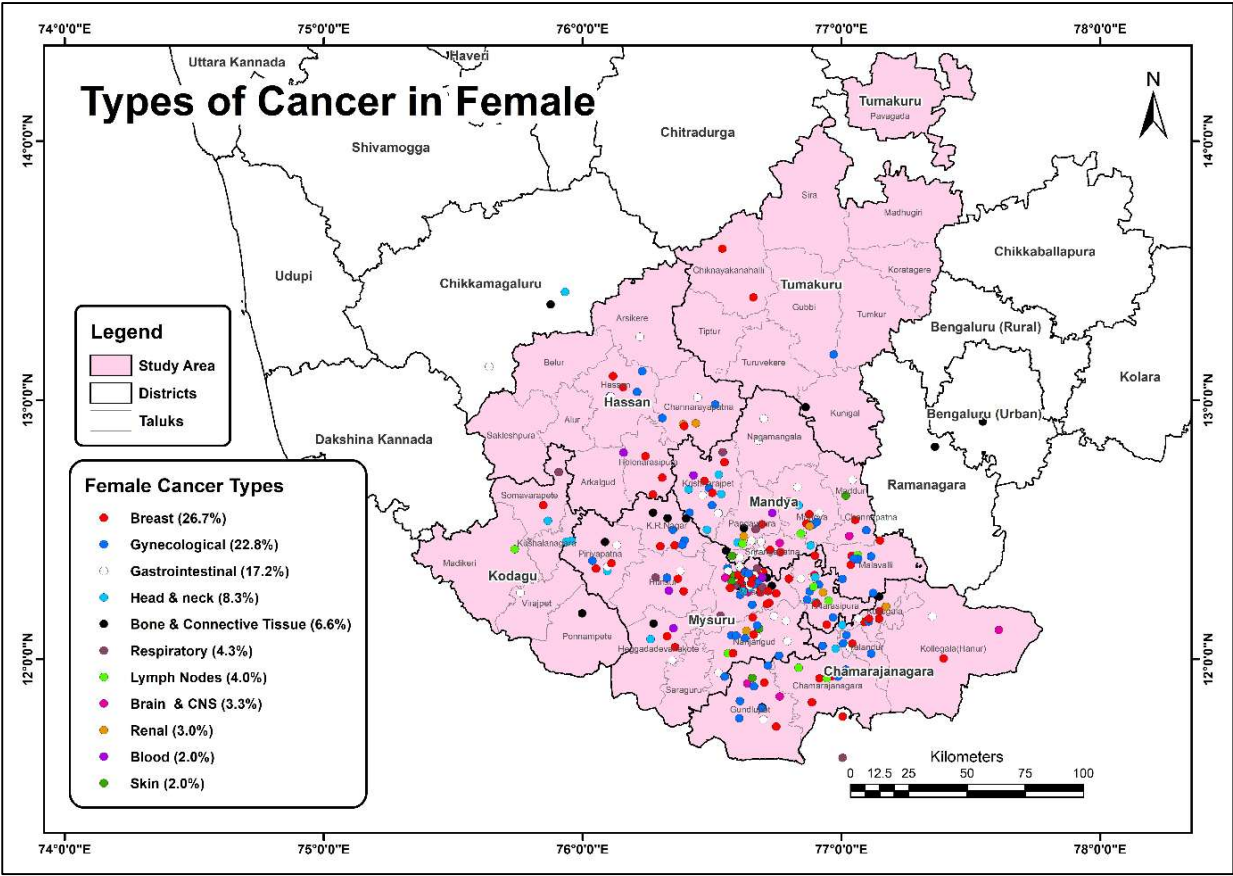


Figure 2: Spatial distribution of the study population according to type of cancer

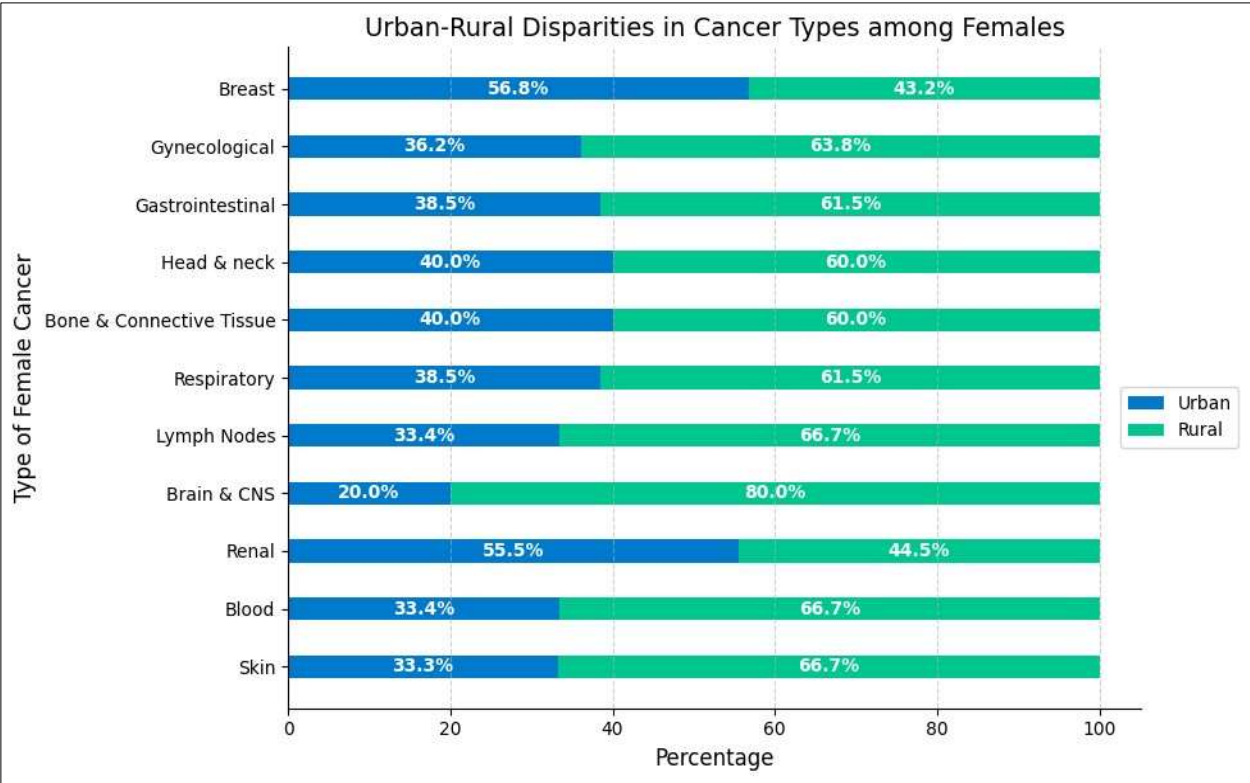


Figure 3: Urban Rural Disparities in cancer types among Females (n=303)

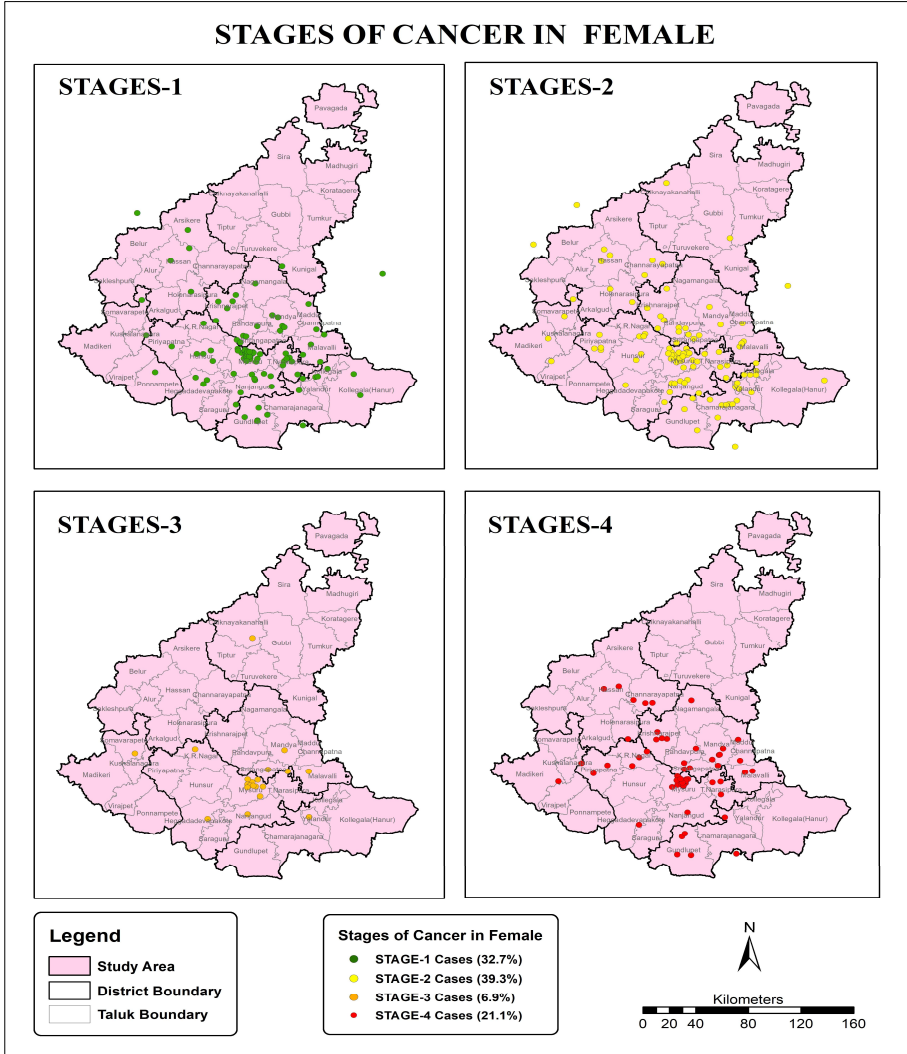


Figure 4: Spatial distribution of the stages of cancer in females

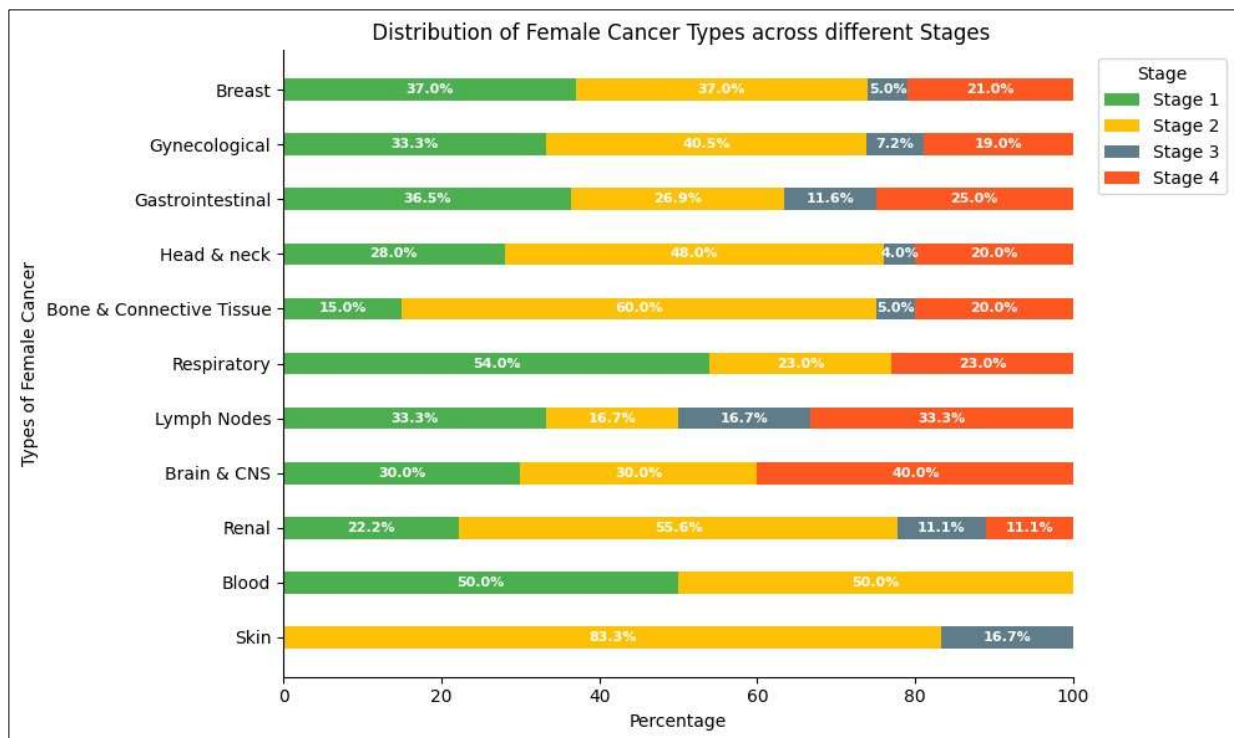


Figure 5: Distribution of female cancer types across different stages

DISCUSSION

This feasibility study utilized GIS for retrospective HBCR data obtained from a Tertiary Care Hospital for understanding and identifying spatial patterns and trends of women's cancer cases.

The majority (44.2%) of Women cancer cases in this study were within the age group of 40-59 years, emphasizing the cancer in middle-aged individuals. A minimal percentage of patients (1.3%) were in the age group of 0-19 years, suggesting that cancer cases is relatively rare in younger Women. Consistent with these findings, another study reported the median age of cancer diagnosis as 49.5 years.¹⁴ The majority of the study subjects were married (74.9%), the study reflects a predominantly 57.4% of patients are from rural areas, underscoring the importance of considering regional disparities in cancer cases.

The temporal distribution of cancer cases from 2019 to 2022 shows a decline, with the proportion of registered cases decreasing from 31% in 2019 to 27.4% in 2022. This reduction can plausibly be attributed to the COVID-19 pandemic and the associated restrictions during 2020 and 2021. Several studies have documented those interruptions in cancer care during this period were linked to fear of infection, government-mandated stay-at-home orders, and the redeployment of healthcare staff toward COVID-19 management.^{15,16}

Half of the study participants (50.8%) were diagnosed using X-ray or imaging techniques, while the remaining half (49.2%) relied on microscopic methods, showcasing the diversity in diagnostic approaches. A substantial proportion (69.6%) of study

participants received C+S+R treatment, pointing towards combined surgery, chemotherapy, and radiation therapy in managing Women's cancers. The majority (79.2%) underwent curative or radical treatment for RI, indicating an aggressive approach to managing the disease at its root.

The spatial distribution of the map represents the Women's cancer cases across 36 taluks in South Karnataka. The majority of the cases were reported by Mysuru (52.5%), followed by Mandya (20.4%) and Chamaraajanagar (13.2%) districts. The top three reported cancers, Breast, Gynecological, and Gastrointestinal cancer are prominently observed in these regions. Similarly, another study found that, higher incidences of breast cancer were observed in specific taluks, including Hunsur, KR Nagar, Nanjangud in Mysuru, and Chamrajanagar and Gundlupet in Chamaraajanagar District.¹⁷

The geographical clustering of cancer cases around healthcare centers is a well-documented phenomenon, reflecting both the catchment area of these facilities and the healthcare-seeking behavior of the population. In this context, the concentration of cases in Mysuru suggests that the tertiary care hospital plays a pivotal role in serving as a medical hub for cancer-related services, drawing patients from neighboring districts and also it implies the necessity of incorporating maps into routine health needs assessments to guide interventions, such as awareness programs.

Breast and renal cancers are more prevalent in urban areas (each exceeding 55%), aligning with patterns commonly associated with urbanization, lifestyle, and access to healthcare services.⁹ The majority of other cancer types, including Gynecological, Gas-

trointestinal, head & neck, bone & connective tissue, respiratory, lymph nodes, blood, and skin cancers, are reported more than 60% from rural areas. In another study, the Urban population exhibited higher combined cancer cases compared to rural populations, with a notable urban decline of 10.2%, a 4.8% decline observed in rural areas.¹⁸ This observation brings attention to the multifaceted challenges faced by rural populations, ranging from limited healthcare accessibility to socioeconomic factors and awareness disparities. The cancer types traditionally associated with lifestyle factors and environmental exposures in rural areas suggests a need for targeted interventions addressing these specific cancers.

The remarkable finding of this study is that 80% of brain and CNS cancers were reported from rural areas. This disproportionately high rural burden likely stems from delayed diagnosis and referral bottlenecks. A systematic review has shown that non-specific symptoms, limited community awareness, poor access to neuroimaging, and fragmented referral pathways contribute to prolonged diagnostic intervals among rural patients.¹⁹ These challenges highlight the urgent need for strengthened healthcare infrastructure to facilitate timely screening and diagnosis, along with targeted awareness campaigns in remote areas. In addition, the elevated rural occurrence of brain and CNS cancers may be influenced by multiple factors, including environmental exposures, genetic predispositions, and occupational hazards that are more prevalent in rural populations.^{20,21}

The spatial distribution of cancer cases across different stages provides valuable insights into the staging patterns of Women's cancer visually. The higher cases of Stage 2 (39.3%) and Stage 1 (32.7%) cancer cases in the were reported in the studied population. This can be attributed to several factor's indicative of improved early detection practices. Initiatives such as screening programs, awareness campaigns, and enhanced diagnostic capabilities contribute significantly to identifying cancer at its earlier and more treatable stages. In contrast, a similar study reported that 50.9% of patients were diagnosed at advanced stages (Stage III and Stage IV).²²

The lower numbers in Stage 4 (21.1%) and Stage 3 (6.9%) cancer cases suggest potential challenges in diagnosing cancer at later, more advanced stages within the study population. This could be attributed to various factors, including limited access to healthcare services, delayed healthcare-seeking behavior, and insufficient awareness of cancer symptoms. Geographic, socioeconomic, or cultural barriers may impede timely access to healthcare facilities, leading to delayed diagnoses.⁶

The distribution of Women's cancer types across different stages provides valuable insights into the staging patterns of various malignancies. Notably, the figure highlights a predominant concentration of cases in the early stages, with more than 70% re-

ported at Stage 1 and Stage 2. This trend is particularly pronounced in respiratory cancer, where 54% of cases are identified at Stage 1, and skin cancer, with an impressive 83.3% reported at Stage 2. The higher cases of early-stage diagnoses in these specific cancers suggests effective screening programs, heightened awareness, and possibly distinct characteristics of these malignancies that facilitate early detection. Conversely, lymph node cancer & skin cancer show a higher proportion (16.7% each) at Stage 3, indicating challenges in early detection or differences in the natural progression of the disease. Notably, brain and CNS cancer have a substantial proportion (40%) reported at Stage 4, emphasizing the need for improved early detection strategies for this particular cancer type.

This feasibility study of utilizing GIS is to showcase the potential utility in informing healthcare and public health professionals, as well as other policymakers, about the imperative for geographical needs assessments. The primary objective of health mapping using HBCR data is not merely to identify statistically significant relationships, but rather to gain initial insights and understanding into how patterns and trends vary across space. The ultimate goal is to uncover potential drivers behind the spatial variations observed.

STRENGTH, LIMITATIONS, AND RECOMMENDATIONS

A key strength of this study lies in its integration of GIS with HBCR data to visualize spatial patterns of women's cancer cases in a defined hospital catchment area. This approach offers a practical and scalable framework for institutions to explore service coverage gaps, identify potential clusters of advanced-stage cancers, and inform local outreach or screening efforts. To our knowledge, this is the first study of its kind in southern Karnataka to explore hospital-reported cancer case distribution using spatial tools, thereby contributing novel insights to the HBCR.

Based on these findings, we recommend that GIS tools be incorporated into routine HBCR reporting to enhance institutional surveillance and planning. Such integration would enable cancer centers to monitor geographic disparities in real time and prioritize outreach in underserved areas. Collaboration with PBCRs is also essential to generate population-level estimates and validate hospital-level trends.

The GIS framework demonstrated here is scalable to other hospitals and regions, particularly those with HBCR systems in place. However, successful expansion requires addressing challenges such as standardizing address data formats, ensuring geocoding accuracy, and maintaining interoperability across institutions. Despite these constraints, this study illustrates the feasibility and value of embedding spatial

intelligence into cancer registry systems to support evidence-based cancer control strategies.

However, the study is not without limitations. As HBCR data are limited to patients who accessed care at a specific tertiary hospital, the findings are not generalizable to the broader population. The study does not estimate incidence or prevalence, and apparent spatial clusters may be influenced by hospital proximity, referral practices, and care-seeking behavior. Furthermore, the use of postal PIN codes as the geocoding reference reduces geographic precision, since PIN codes cover relatively large areas and do not always capture intra-taluk or neighborhood-level variation. The absence of spatial statistical methods such as cluster detection or population-adjusted incidence mapping further limits epidemiological interpretation. Despite these constraints, the study successfully demonstrates the technical feasibility and interpretive value of GIS in institutional cancer surveillance.

CONCLUSION

This feasibility study demonstrates the utility of integrating Geographic Information System (GIS) tools with Hospital-Based Cancer Registry (HBCR) data to visualize the spatial distribution and staging of women's cancers in Mysuru District, Karnataka. The findings reveal the predominance of breast, gynecological, and gastrointestinal cancers, the dominance of early-stage presentations, and notable rural-urban disparities in case distribution. These results underscore the potential of GIS to support institutional planning, guide resource allocation, and identify priority areas for intervention. Future research should incorporate spatial statistical methods and extend analyses to multi-hospital HBCR datasets to validate these findings and strengthen their applicability. This study provides a foundation for embedding spatial intelligence into cancer care planning and highlights the importance of geographically informed strategies to reduce disparities in access, diagnosis, and outcomes.

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Individual Authors' Contributions: **NM** was responsible for data collection. **MSM** contributed to manuscript writing, while **CM** assisted with manuscript writing and formatting. **SBM** and **MC** carried out the spatial analysis. **SKS** was involved in table creation, and **DVSKM** contributed to the interpretation of the tables. **SBC** provided supervision. **MB** was

responsible for supervision, methodology, and overall review of the manuscript.

Availability of Data: The data utilized in this study, comprising the Hospital-Based Cancer Registry (HBCR) data and Geographic Information System (GIS) spatial analysis, are not publicly accessible due to privacy and ethical constraints. Access to the data can be requested from the corresponding author, subject to approval from the institutional ethics committee. Requests will be evaluated on a case-by-case basis, considering confidentiality and ethical guidelines.

Declaration of Non-use of Generative AI Tools:

This article was prepared without the use of generative AI tools for content creation, analysis, or data generation. All findings and interpretations are based solely on the authors independent work and expertise.

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