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# Spatial Distribution of Cancer in Trivandrum, India Using Geographic Information System: Pilot Study

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**Abstract:** A remarkable finding is that Kerala's capital Trivandrum has the highest crude (CR) cancer incidence rate (except Aizwal, North East) in India. Aim of this study was to create density map of all cancers together and common cancers by gender in Trivandrum. Cancer registry incidence data from Trivandrum Taluk for the year 2012 and Geographic Information System (GIS) were used. Incidence data was geocoded using Google Earth Software. Landforms and geomorphological map were prepared using satellite remote sensing technique. Slope map was created using 3D analyst and digital elevation model. GIS analysis was done using ArcGIS Ver. 10 software. From the cancer registry data, CRs (per 100, 000) (n=1804) were 159 in males and 157 in females in the Taluk. From density maps CRs ranged 150-494 in 58% areas (CR >300 in 14.8% area) in males and CRs ranged 150-551 in 54.5% areas (CR >300 in 14.5% area) in females. 21.7% of all cases were in coastal, 65.5% in residential and 12.8% in forest areas. In males, common cancers were lung (CR >50 in 10% area) and prostate (CR >50 in 6.5% area) and in females, breast (CR >100 in 10% area) and thyroid (CR >50 in 5% area), 36.3% of breast cancer in residential (p= 0.021) and 20.8% of thyroid cancer in coastal areas (p=0.001).In *Conclusion:* This study located high cancer incidence areas in Trivandrum Taluk and demonstrated effective use of cancer registry data and technological advancements in cancer research.

**Key words:** Geographic Information System · Spatial Analysis · Geocoding · Disease Mapping · Cancer

## INTRODUCTION

Cancer is a major health issue and there were 14.1 million new cancer cases, 8.2 million cancer deaths and 32.6 million people living with cancer (within 5 years of diagnosis) in 2012 worldwide [1]. It has been predicted that India's cancer burden will nearly double in the next 20 years and the incidence is projected to rise to 1.7 million individuals in 2035 [2]. The disease is emerging as a public health threat in Kerala, South India. A remarkable finding is that Kerala's capital Thiruvananthapuram has the highest crude cancer incidence rate in the country [3]. Based on the available incidence rates in Thiruvananthapuram, it was estimated that new cancer cases diagnosed were 48, 050 (22, 991 males and 25, 060 females) in Kerala for the year 2012 [4].

Spatial assessment of cancer is very essential for environmental research. Cancer registry generates incidence and mortality statistics in a specific area like crude (CR), age-specific and age standardized (ASR) rates and these rates are useful for planning and administration. Geographic distribution of cancer is very useful to optimize cancer control programmes. Based on the availability of sophisticated mapping techniques, cancer registry summary figures can be used for assessing the density of cancer spatially. It has been reported that spatial representation of cancer can be made possible by the simultaneous examination of population and outcome [5]. Geographic Information Systems (GIS) have been continuously refined for the spatial analysis of cancer incidence and mortality. Disease mapping, geographic correlation studies, risk assessment in relation to a pre-specified point or line source and disease clustering have been utilized in cancer research with the help of GIS [6].

In the present study, cancer incidence data from Thiruvananthapuram Taluk registry was geocoded using GIS to assess the spatial distribution of cancer. Cancer density map of all and three common cancer sites

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by gender were plotted and the relationship between cancer incidence and its land cover as well as elevation of the Taluk was examined.

## MATERIALS AND METHODS

Thiruvananthapuram Taluk is situated in the south western part of the state of Kerala between 76°47'–77°01' East longitude and 8°21'–8°40‘North latitude, covers an area of 300 sq.km. The Taluk population was 1.14 million in 2011 [7] and the estimated (distribution difference method) population for the year 2012 was 11, 43, 784 (5, 51, 514 males and 5, 92, 270 females). Administrative structure of the Taluk consists of 86 ‘wards’, 10 ‘panchayats’ and 5 ‘villages’. Ward is the smallest unit in the urban area which includes a population of 6000-10, 000. Panchayats are the village units in the rural area which include a population of 20, 000-40, 000. Ninety percent of the Taluk population is urban. The 101 administrative units (86 wards, 10 Panchayats and 5 villages) were considered for assessing the spatial distribution of cancer incidence in the Taluk.

Thiruvananthapuram Taluk registry has been included under the national cancer registry programme (NCRP) of Government of India since 2006. Cancer cases diagnosed from 1st January 2012 to 31st December 2012 from the Taluk were used for the present study. Permanent residents (duration > one year) of the registry area constitute the cancer cases. Cancer registry data collection system is active and has been collected from more than 60 hospitals and 7 pathology laboratories. Address linkage of data, obtained from pathology laboratories were made. Data has been provided voluntarily, however, an administrative letter was provided in 2011 by the Government of Kerala to all health authorities in the district and hence co-operation from all hospitals have been obtained. Duplicate registrations were eliminated and care was taken to see that multiple entries of the same patient were not made in the records after computerizing the data. Necessary information was abstracted using the incidence form and data entry was done using the software provided by the NCRP. Using the Taluk registry data for the year 2012, CR and ASR (direct method using world standard population) per 100, 000 person-years were estimated [8] for all cancers and three common cancers by gender (lung, prostate and oral cavity among males; breast, thyroid and ovary among females).

Locations (address geocoding) of cancer cases in this study were obtained using Google Earth software (Version 5.1.) [9]. Boundaries of the 101 administrative units of the Taluk were taken from Diva Gis database [10]. Landforms and geomorphological map were prepared using satellite remote sensing technique. Major sources of elevation information of the study area were obtained from Indian Remote Sensing Satellite CartoSAT-1, which provides Digital Elevation Model (DEM) of the area at a spatial resolution of 30 m and captures more detailed information [11]. Relationship between elevation and cancer types was assessed using distribution map of cancer cases. Slope map of the study area were created using 3D analyst and spatial analyst extension in ArcGIS software [12] by using CartoSAT-1 based DEM. Land cover was classified as residential area, agricultural area and coastal area using Remote Sensing supervised classification techniques. Isopleth maps used contours to measure elevation. Elevation was classified as 0–20 m, 20-40 m, 40-60 m, 60-80 m and > 80 m. The spatial analysis function “Intersect” in ArcGIS 10 was used to determine the relationship between cancer cases with land cover and elevation. Statistical significance between cancer types and land cover was assessed using Pearson chi square test.

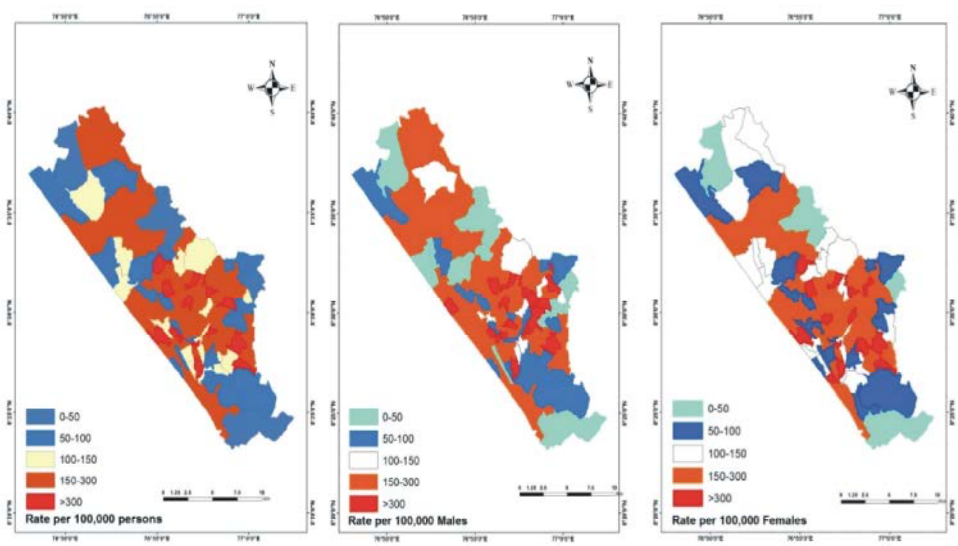
## RESULTS

A total of 3864 cancer patient details were collected from the various hospitals (81.1% from government), who were diagnosed during 2012 from the Taluk. The source of registration was 39.8% from the Regional Cancer Centre, Thiruvananthapuram and 30.0 % from the government medical college hospital, 11.3% from the other government hospitals and 11.8% from the private hospitals and 7.1% from Death Certificate Only-. After eliminating duplicates, a total of 1840 cancer patients were included in the registry and 1, 804 were included (48.9% males and 51.1% females) for the present study (34 patients were eliminated as sufficient address was not available to identify the location).

Age at diagnosis was less than 50 years in 23.6% males and 33.4% in females. The average age of all cases were 58 ± 0.4 year and it breaks down to 59.5 ± 0.5 for males and 56.5 ± 0.5 for females. Overall ASRs among male was 133.1 per 100, 000, whereas for female, this value was 126.1 per 100, 000. Overall CRs were 158.8 and 157.3 per 100, 000 males and females respectively for the year 2012.

Table 1: The number and relative proportion (%) of cancer types by land cover classes among gender

| | Coastal area | | Residential area | | Forest Area | | Total | |
|---|---|---|---|---|---|---|---|---|
| Cancer types | # | % | # | % | # | % | # | $\chi2$ & p_value |
| Males | | | | | | | | $\chi2$ = 1.57 p = 0.456 |
| Lung | 21 | 12.0 | 56 | 9.4 | 18 | 16.1 | 95 | |
| Prostate | 18 | 10.3 | 55 | 9.2 | 8 | 7.1 | 81 | |
| Oral | 20 | 11.4 | 51 | 8.6 | 10 | 8.9 | 81 | |
| Other | 116 | 66.3 | 434 | 72.8 | 76 | 67.9 | 626 | |
| Total | 175 | 100.0 | 596 | 100.0 | 112 | 100.0 | 883 | |
| Females | | | | | | | | $\chi2$ = 109.4 p = 0.001 |
| Breast | 65 | 30.1 | 213 | 36.3 | 29 | 24.4 | 307 | |
| Thyroid | 45 | 20.8 | 20 | 3.4 | 8 | 6.7 | 73 | |
| Ovary | 10 | 4.6 | 40 | 6.8 | 9 | 7.6 | 59 | |
| Other | 96 | 44.4 | 313 | 53.4 | 73 | 61.3 | 482 | |
| Total | 216 | 100.0 | 586 | 100.0 | 119 | 100.0 | 921 | |




All case together Male Female

Fig. 1: Distribution map of cancer incidence rate among gender -Thiruvananthapuram Taluk (2012)

To illustrate the spatial distribution of cancer, density map of cancer cases in the study area is plotted in Fig. 1. Considering all case together, among 101 administrative units, 41.6 % places showed incidence rate ranged 0-150 and 58.4% places showed incidence rate ranged 150- 494. Among males 42.4 % places showed incidence rate ranged 0-150 and 57.6% places showed incidence rate ranged 150- 495. Among females 45.5 % places showed incidence rate ranged 0-150 and 54.5% places showed incidence rate ranged 150- 551.

The most common cancers (rates per 100, 000) among males were lung cancer (CR: 17.0, ASR: 13.9), prostate cancer (CR: 15.8, ASR: 12.9) and oral cancer (CR: 15.4, ASR: 12.6). In the case of the spatial distribution of males 46.5, 51.5 and 40.4% places reported no prostate cancer, lung cancer and oral cancer respectively. 11.8% places showed prostate cancer incidence rate ranged 0-20 and 41.6% places showed incidence rate ranged 20-106. 7.9% places showed lung cancer incidence rate ranged 0-20 and 40.6% places showed incidence rate ranged 20-76. 21.9 % places showed oral cancer incidence rate ranged 0-20 and 38.5% places showed incidence rate ranged 20-70 (Fig. 2).

From the registry figures, the most common cancers among females were breast cancer (CR: 52.4, ASR: 40.1), thyroid cancer (CR: 13.3, ASR: 10.9) and ovarian cancer (CR: 9.5-, ASR: 7.8). The spatial distribution of females among 101 administrative units, 4.9 %, 37.4% and 59.4% places reported no breast cancer, thyroid cancer and ovarian cancer respectively. 35.7 % places showed breast cancer incidence rate ranged 0-50 and 59.5% places

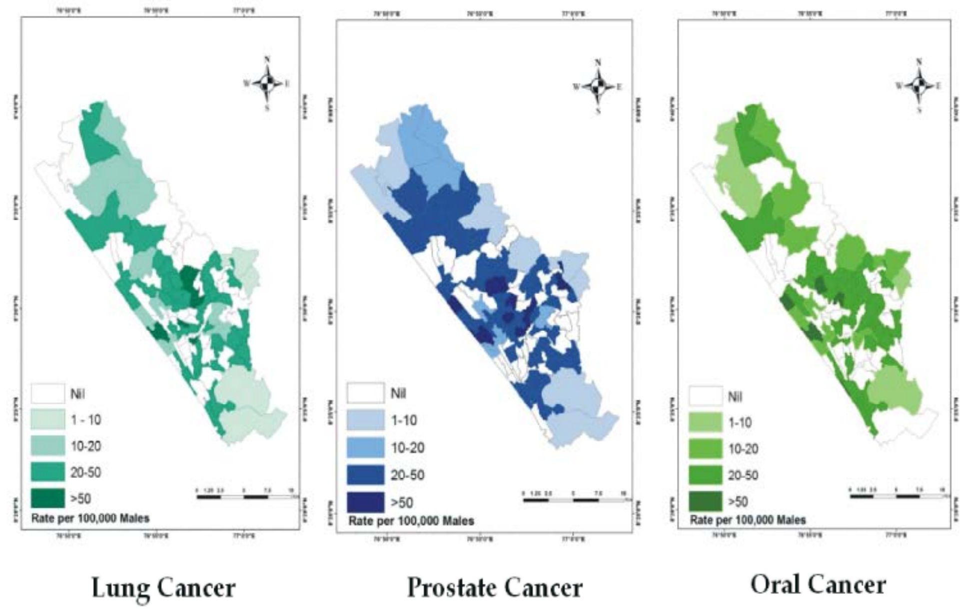



Fig. 2: Distribution map of leading cancer type in Male -Thiruvananthapuram Taluk (2012)

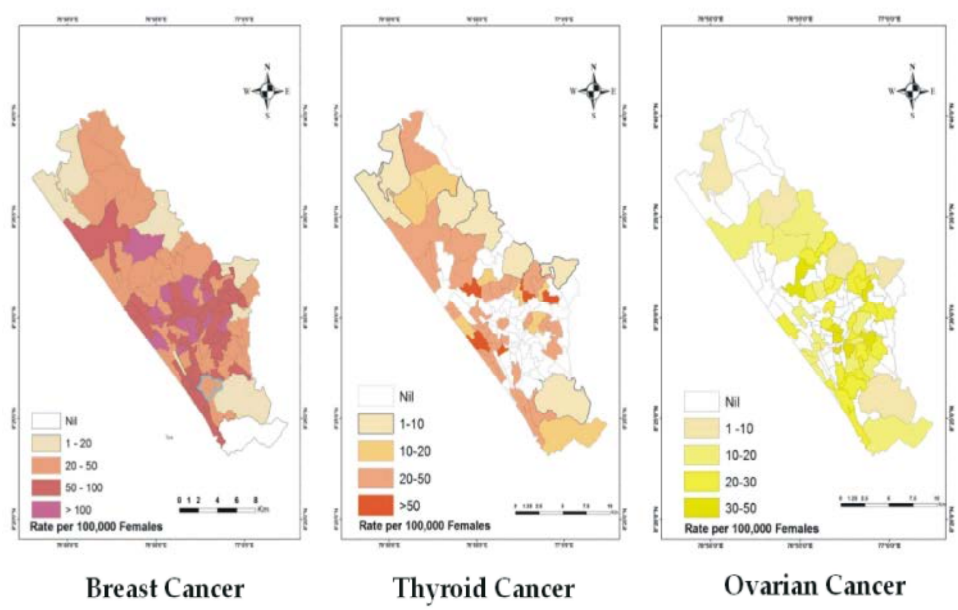
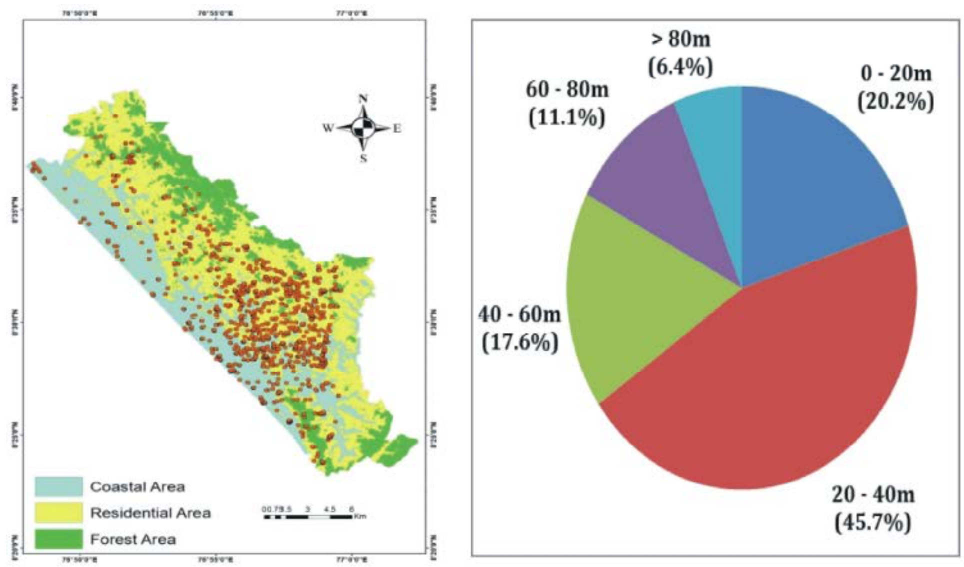



Fig. 3: Distribution map of leading cancer type in Female -Thiruvananthapuram Taluk (2012)

showed incidence rate ranged 50-268. 24.8 % places showed thyroid cancer incidence rate ranged 0-20 and 37.8% places showed incidence rate ranged 20-116. 15.9 % places showed ovarian cancer incidence rate ranged 0-20 and 24.8% places showed incidence rate ranged 20-98 (Fig. 3).

The number and percentage of cancer types by land cover classes are shown on Table 1. To enable the statistical analysis, the cancer types were reduced to six common cancer types (lung, prostate & oral cancer among males and breast, thyroid, & ovarian cancer in females). On examination; 21.7% of all cancer cases were in coastal area, 65.5% in residential areas and 12.8% in forest area. Among males; 17.8% of cancer cases were in coastal area, 67.5% in residential areas & 12.7% in forest area and there was no significant relationship between cancer types and land cover among males ($\chi^2$ = 1.57, p = 0.456). The occurrence of female cancer was 23.5% in coastal area, 63.6% in residential areas and 12.9% in forest area. There was a significant relationship between cancer types




Land Cover Elevation Classes

Fig. 4: Distribution of cancer cases by land cover classes and % of cancer cases in Elevation classes

and land cover among females, $\chi2$ = 109.4, p = 0.001. Breast cancer occurred 36.3% in residential areas (p = 0.021) and thyroid cancer occurred 20.8% in coastal areas (p = 0.001) (Fig. 4).

It was found that 20.2 % of all cancer cases occurred at 0–20 m, 45.7% at 20-40 m, 17.6% at 40-60 m, 11.1% at 60-80 m and 6.4% at an elevation of more than 80 m. The spatial distribution of cancer cases by land cover classes and elevation classes were explained in Fig. 4.

## DISCUSSION

In the present analysis we observed that cancer incidence varied from one area to another and the rates were very high (>300 per 100, 000) in some specific areas in Thiruvananthapuram Taluk in both gender. This spatial analysis by utilizing sophisticated mapping techniques and cancer registry data was first of its kind in Kerala. This multi-disciplinary exploration has brought health service data into GIS platform, which enhanced the visualization of spatial patterns of cancer incidence in Thiruvananthapuram.

Utilizing cancer incidence in five continents data, it has been estimated that the incidence rates were 268 in more developed regions, compared to 148 in less developed regions in 2012 [1]. Contrary to these rates, it was observed from the present cancer density map of the 101 administrative units of Thiruvananthapuram, incidence rate was >300 in 15% of the area in both gender and this was much higher than the rates in developed countries. This kind of geographical analysis would help to locate the high cancer incidence areas.

Common cancers in the Taluk registry were lung, prostate and oral cancer among males. Even though the crude incidence rate was < 20 for these cancers, the density map indicated that the rate was >50 in 10% area for lung cancer, in 7% area prostate cancer and in 5% area oral cancer. Common cancers among females were breast, thyroid and ovary. Breast cancer incidence rate was >100 in 10% of the area and these rates were much higher than the rates in developed countries [1]. Environmental and epidemiological research is needed for determining the causes of higher incidence of this cancer in the specific area of the Taluk.

Studies have been reported spatial distribution of several cancers such as prostate cancer and its relation to environmental carcinogens [13], High incidence of breast cancer in residential areas and high incidence of thyroid cancer in forestry areas have been reported [14]. In the present analysis also high incidence of breast cancer occurred in residential areas whereas thyroid cancer incidence was high in coastal areas. Thiruvananthapuram is one of the coastal districts in India and it has been reported that high incidence of thyroid cancer in females occurred in southwest coastal districts of India [15]. Thyroid cancer is the second leading cancer among women in the present study area and the rate was >50 in 5% area. This disease has been noted to be common in other coastal areas of the world with large populations of fishermen [16]. Epidemiological studies are needed for finding the increase in the thyroid cancer incidence in coastal areas.

In this study 65.9% of all cancer cases occurred at 0-40 m elevation. A number of environmental variables are correlated with land elevation and have been studied in relation to cancer rates. A higher incidence of prostate cancer has been observed in more northern areas in the U.S. (that typically have higher land elevations) compared to southern areas [17]. Land elevation and cancer death rates in the U.S. revealed lower cancer death rates in higher elevations. [18-20]. In Iran reports showed differences in cancer incidence based on age, sex, city of residence and non-cluster cancers and these type of studies can support the cancer prevention and screening programs focusing hypothesis and pave the road for decision makers and planners in the health system [21].

The present pilot study had some weaknesses. Incidence data was limited and the populations in some areas are too small to obtain stable results. It is needed to combine the data for several consecutive years. Secondly, as the age- and gender-specific population of area is unavailable, hence ASR could not be calculated by each administrative unit. The accuracy of the rate calculated depends upon the size of the denominator population. Populations within administrative areas tend to vary geographically and this variation also affects the reliability of the data and accordingly the accuracy and reliability of the results will vary geographically across the map [22].

Cancer is caused by a combination of environmental and genetic factors. Cancer is influenced by environment, lifestyle and diet on one hand, hereditary and spontaneous mutations on the other [23]. Another limitation of the study was in obtaining complete permanent address of cancer cases. Often patient's complete permanent address has not been obtained. As cancer registry data collection system is active in India, data abstraction for the registry has been made from various hospitals retrospectively. Hence there is a need to obtain accurate residence status of patients for assessing cancer burden. Also residential address has not been geocoded in India. Errors in address geocoding could also contribute to misclassification of administrative units. Actual house may lie away from a road or street obtained from Google Earth Software and therefore affects proximity measures. Present study only mapped spatial distribution of cancer cases in a small population in Kerala.

## CONCLUSIONS

This study demonstrated effective use of GIS in cancer research and visual representation of cancer incidence in geographical area and to locate high incidence areas through density maps utilising technological advancements. Similar studies with larger population after verification of the location of the cancer cases for geocoding are to be conducted for doing further environmental cancer research.

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