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# Geospatial Analysis of Cancer Cases in the Eastern Black Sea Region of Turkey

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## Introduction

Cancer has remained an important health issue in recent years. Examining variations of cancer cases temporally and spatially is necessary to develop strategies to combat its occurrence and to put cancer control programmes into practice. Creating cancer maps is necessary for obtaining information such as the location and frequency of cancer cases, the geographic distribution of cancer types and the location of the highest densities of cases. Consequently, creating more reliable and precise data infrastructures will increase the number of accurate decision making options available and aid in determining how and where to implement control strategies.

Numerous studies have been conducted on cancer epidemiology, the majority of which are thematic mapping studies including the observation of spatial distribution of cancer (Pickle et al., 2007; Kulldorff et al., 2006; Brewer, 2006; Morra et al., 2006; Jacquez, 2004; Berke, 2004; Vieira et al., 2002). In addition, more specific cancer studies exist in which advanced statistical analyses are performed (Yomralioglu et al., 2009; Draper et al., 2005; Greiling et al., 2005; Oliver et al., 2005; Flinton and Walters, 2004; Diggle, 2000).

In Turkey, the number of studies on cancer epidemiology remains insufficient. Although control policies were developed and employed against cancer by the Turkish Ministry of Health (2004), comprehensive cancer-mapping for the whole country are not yet available. The studies conducted are mostly regional and oriented toward a specific feature of cancer due to the

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problems regarding reliable cancer statistics for all of Turkey. In line with the current cancer policies, the importance of a cancer registry has gradually increased in recent years. Some regions and cities have initiated pilot schemes for a cancer registry, including the cancer registry centre in the city of Trabzon, located in the Eastern Black Sea region of Turkey.

Spatial epidemiology studies aim to investigate the relationships between important health and environmental factors. Information about the causal factor of the disease is vital for the investigation of the relationship between the geography and the disease. For the spatial relationships among health issues to be explored, information about the disease and the environmental factors that influence it should first be collected and then be analyzed using statistical methods in line with the requirements. Such analyses can be performed effectively using GIS, which can evaluate spatial information, information related to health issues and information related to environmental factors together.

In this study, cancer density maps were produced using GIS techniques for an area that comprises seven cities in Turkey. A model proposal was developed through which statistical studies could be performed about whether carcinogenic environmental factors affect the cases in the defined cancer density areas. Mapping cancer cases enables the consideration of the cancer densities within each administrative unit by also considering the population sizes of these administrative units and the demonstration of an integrated approach to addressing carcinogenic environmental factors. Several studies oriented toward cancer mapping and defining cancer cluster areas exist. Studies that investigate the impacts of environmental factors on cancer focus primarily on more specific issues, including examinations of the relationships between a specific type of cancer and a specific carcinogenic factor. Studies that examine all of these factors in an integrated framework are needed. This study proposes a higher-scale integrated approach that could guide studies on cancer and this proposal promotes the simultaneous operation of the desired specific studies and the consideration of other factors. Different thematic cancer maps have been created using GIS for more detailed studies in the region in epidemiological topics. Consequently, the results of this study would help develop and apply cancer control programmes in the country.

## Background and Context

Cancer incidence has been increasing worldwide and specifically in developing countries. In Turkey, the cancer incidence is calculated as 180-200 per 100,000 people, a rate half that of the European Union countries; this difference is due in part to the age distribution of the population of each region. Turkey expects 144,000 new cancer cases among its population of 72 million and current cancer incidence of 200 per 100,000 (Tuncer, 2009).

The mapping of cancer incidence has enabled the development of important hypotheses about the carcinogenic factors. Due to suitable statistical map presentation techniques, the spatial representation of the density of cancer is made possible by the simultaneous examination of population and cases (Thomas, 1990).

Health geography is a discipline that examines how diseases and health services are distributed across the globe. Scientists have investigated the relationship between health and geography for centuries. Today, the powerful tool used in these studies is GIS technologies (Lang, 2000). The use of GIS in the public health increases the efficiency of spatial analyses and enhances the developments of statistical methods in epidemiology.

GIS is used in community health programmes to monitor developmental and spreading stages of diseases, to assess environmental risks, to develop control strategies related to health issues and to examine issues such as the management and planning of health services. Due to developments in GIS technologies and statistical methods, health and population data in a specified geographical area can be addressed together. Especially in small areas, the investigation of the logical spatial variations or relationships in disease risks becomes possible. Spatial epidemiology is related to both definition and comprehension of such variations. The use of GIS in public health renders the more efficient use of spatial analyses and the development of statistical methods in epidemiology.

## Data and Procedures

### Methodology

Using GIS technologies, this study aims to produce cancer maps for the Eastern Black Sea region of Turkey and to prepare the ground for studies investigating whether the carcinogenic environmental factors are related to the cases in the defined cancer density areas.

For this purpose, the geodatabase has been built with the use of GIS techniques for examining the distribution of cancer cases in the region and thematic maps relating to cancer cases in allocation units was created. Cancer density maps were produced in digital format to examine cancer cases and geographical locations of database content. Geo-statistical analysis was also conducted in a spatial environment.

The presence of data appropriate for the objectives of a study will guide the planned execution of the study. In that case, the existing cancer records limit the accuracy of the descriptive statistical cancer data and analyses for the administrative units.

Figure 1 shows the main methodological structure planned in this study, but general technical methods and steps for developing other similar studies include the following:

- Researching the current literature about health GIS, cancer maps and geostatistics
- Designing and establishing a geospatial database for cancer oriented GIS
- Obtaining cancer statistics for cancer mapping and controlling the address data of cancer cases
- Determining and providing spatial and non-spatial data for the designed cancer based geospatial database and integrating these data into the geodatabase

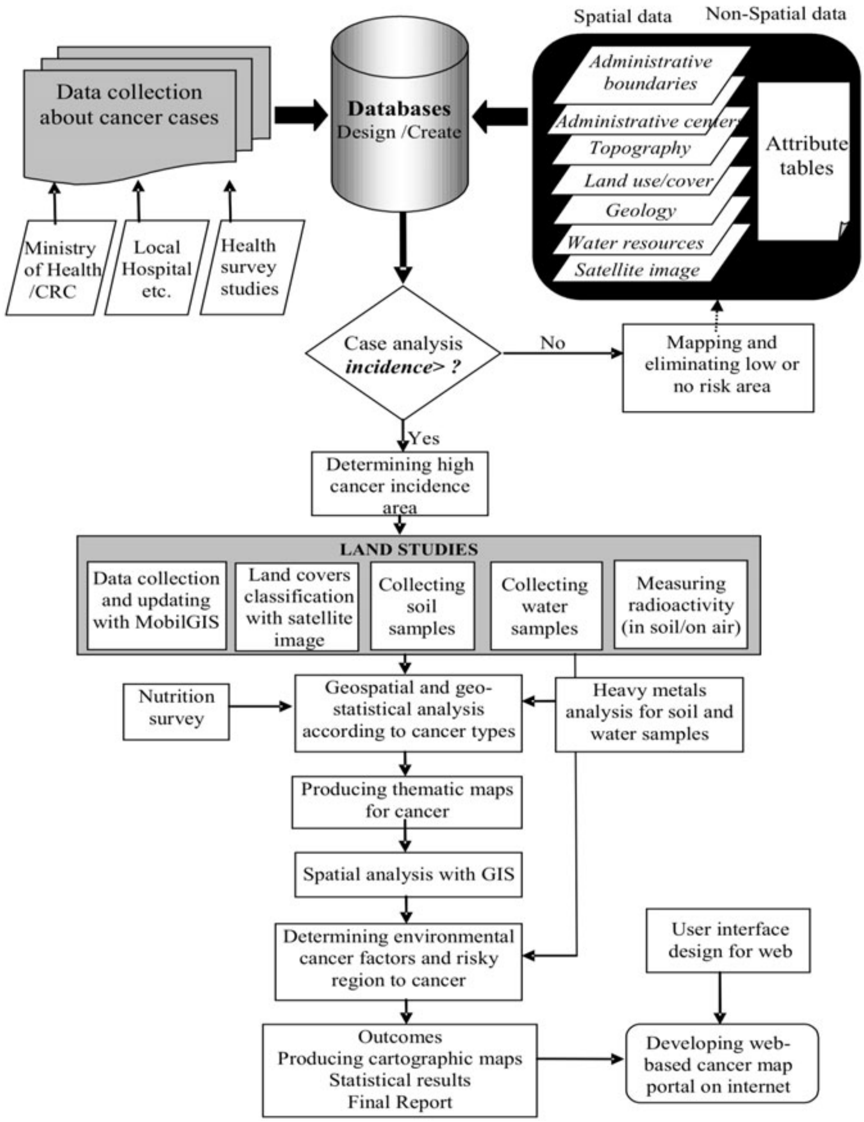


**Figure 1.** A methodological framework of geospatial analysis of cancer cases and associated environmental features.

- Establishing the geo-relationship of cancer cases on the base maps and mapping the spatial distribution of cancer cases
- Performing population-based studies on cancer statistics (incidence, mortality, morbidity, age-standardized cancer incidence rate, etc.)
- Calculating and analyzing the cancer incidence rate for each administrative unit
- Verifying statistical rates associated with cancer risk by cancer types, sex and age groups and integrating these rates into GIS
- Mapping the cancer density maps using geostatistic methods and determining the high cancer density regions
- Applying spatial analysis to the data by cancer types and geostatistic methods
- Determining cancer cluster areas and generating a cancer clustering map
- Examining the relationship between cancer data and geographic features using statistical methods and geostatistics
- Using advanced statistical methods for cancer risk areas
- Identifying high risk areas associated with cancer and environmental exposure
- Representing the final products as thematic maps and other cartography products
- Producing final reports and GIS-based thematic maps

## Cancer-based GIS

Designing the database that enabled the management of the cancer case data and produced spatial statistical data in the GIS environment enabled future studies to use the produced data. The geodatabase managed the data obtained from different sources through different methods by categorizing them in the geospatial data groups of Health (HE), Administrative Unit (AU), Topography (TO), Land Cover (LC) and Geophysics/Environment (GE). In the Cancer-Based Geospatial database shown in Figure 2, each geospatial data group consists of interoperable feature classes.

## Data Inputs

### *Administrative Units and Demographic Data*

The correlation of health events with the geography of residential units was based on administrative units, depending on the scope of the research. The Eastern Black Sea region of Turkey was selected as a case study (Fig. 3), including a total of seven cities (Trabzon, Rize, Artvin, Giresun, Ordu, Bayburt and Gumushane) in the region. Based on this, geospatial data about the administrative centres and boundaries of provinces, counties, districts and villages were collected.

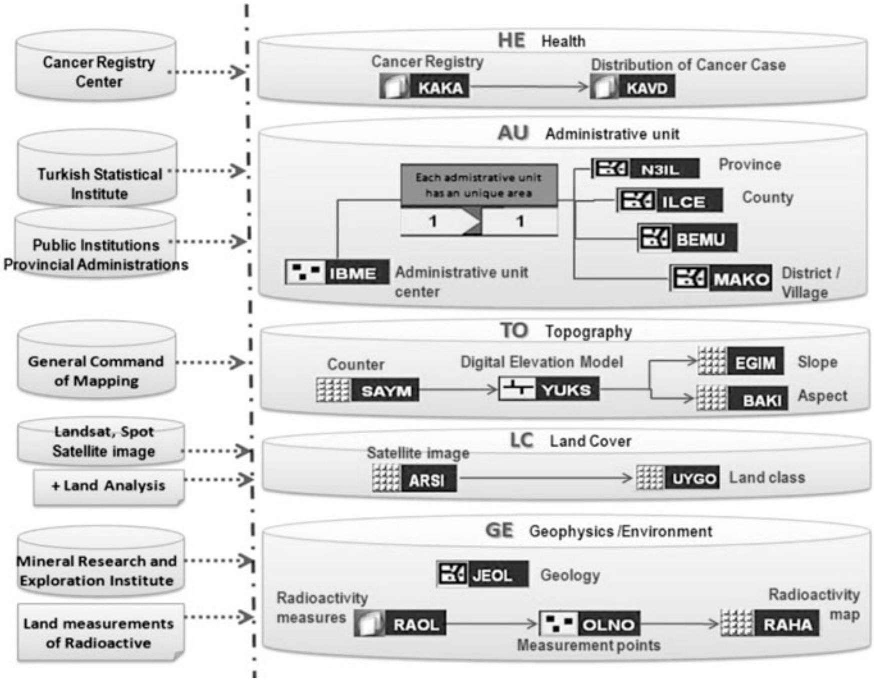


**Figure 2.** Designing the cancer-based geospatial database.

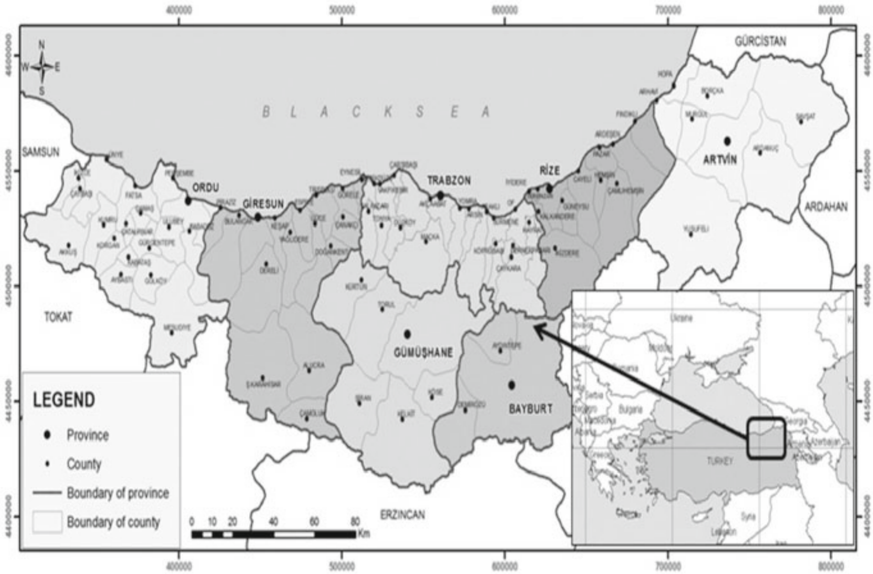


**Figure 3.** Study area: The Eastern Black Sea region of Turkey.

In the Administrative Units data group, provinces, counties and districts/ villages are defined in the GIS "polygon" feature class and the centres of administrative units are defined in the "point" feature class. The Administrative Unit Code (AUC) was used to establish an effective relationship between the databases that represent administrative units and statistical health data. The spatial relationship was established by geocoding according to the AUC defined for each administrative unit.

Demographic data regarding the administrative units were gathered from the Turkish Statistical Institute (TURKSTAT). Demographic information on spatial locations was added to the database containing administrative unit data. Demographic data were further classified according to gender. The demographic data used in calculating cancer density rates in the administrative units were important, and the comparison of the number of cancer cases with the population ensured the accurate interpretation of cancer frequency.

### *Cancer Data*

Address specifications were of the utmost importance for the spatial distributions of cancer cases. Statistical cancer data were obtained from the Provincial Directorates of Health with the permission of the Ministry of Health and consisted of information such as the patient's age, gender, address, diagnosis, the disease's ICD code, topology and the diagnosis date.

Cancer statistics from between 2000 and 2007 were obtained from the Cancer Registry Centres (CRC) in the seven provinces included in the scope of this study in the Eastern Black Sea region of Turkey. In total, 15,299 cancer cases were obtained from these CRCs and included in the cancer database, of which 9,520 were males and 5,779 were females.

To place each case in the cancer database on the map, the Administrative Unit Code was added to the designed database according to the address data of the cases. The relationship between the database that includes cancer cases and the database that includes administrative units was formed through the AUC, enabling the transfer of the cancer database to the designed geographical information system. In addition, with the help of geocoding, each cancer case was identified as a point on the map according to its address information.

### *Topographic and Land Use Data*

Geospatial data that represent height describe Earth's topography and are used in base maps and many other mapping practices. In this study, expressing the relationship of cancer cases to height required contour data. Relevant institutions provided 286 pieces of 1/25,000 scale digital maps of the study area that were obtained through the digitizing of contour lines and formed the base data of this study. Using the Spatial Analysis function, a Digital Elevation Model of the area was produced and converted into grid representation.

The land cover map of the Eastern Black Sea region of Turkey was produced using satellite images, including Landsat ETM+ satellite images from 2000. A total of four satellite images in an East-West orientation cover this area, and correcting the satellite images geometrically concluded the image classification. In the classification of the satellite images, two main methods were used: controlled and uncontrolled classification. While ISODATA algorithm was used in the uncontrolled classification, the Maximum Likelihood algorithm was used in the controlled classification. Extract more information from the existing satellite image, the image enhancement techniques of spectral rationing and principal component transformations were also utilized.

### *Geological Data*

The base map depicting the region's geological structure was another important data layer, with data obtained from the Mineral Research and Exploration Institute. These maps were produced by digitizing 1/100,000 scale analog maps. The produced geological polygon data were incorporated with the geological data and added to the geodatabase. The prepared geology data layer was then subjected to spatial analysis with the cancer data layer, and the data layer produced with the results of the soil test of the region. The region's rock structure was evaluated under seven groups: sedimentary, volcanic, granitoid, alluvial, metamorphic/ophiolithic and other rock types. Figure 4 shows the Geologic Map that represents the region's main geological structure.

### *Radioactivity Data*

Natural radiation originates in space and in elements in the Earth's crust, including uranium-238, thorium-232, radium-226, radon-222 and potassium-40. Analyzing the natural radiation level of a region requires the radiological analysis of that area and involves analyzing its soil, water and air (UNSCEAR, 2000). The area's geological structure also significantly influences its radioactivity level.

To create the radioactivity map of the Eastern Black Sea region of Turkey, radiation levels in the area were measured. The radiation levels measured were the terrestrial outdoor gamma dose rate and the occurrence of radioactive elements, such as uranium, thorium, potassium and cesium, in the soil samples extracted from each test site. Radioactive analyses on the collected soil samples were later analyzed and assessed in the laboratory setting and used to define the locations where radioactivity values would be measured on the map, starting with the prioritized areas. The locations where radioactivity values would be measured were marked according to the cancer density values and proximity to town centres and central transportation lines. Care was taken to distribute the locations homogeneously throughout the region.

After the measurements for radioactivity values were completed, the values from the collected soil samples were analyzed in the laboratory setting. The analysis results were arranged in a table database linked to the geodatabase and designed according to the location coordinates where radioactivity values were measured. Raster surfaces were formed to produce the area's radioactive value maps from the locations with vector data structures. The raster structure was produced using the kriging spatial analysis method, a geostatistical method.

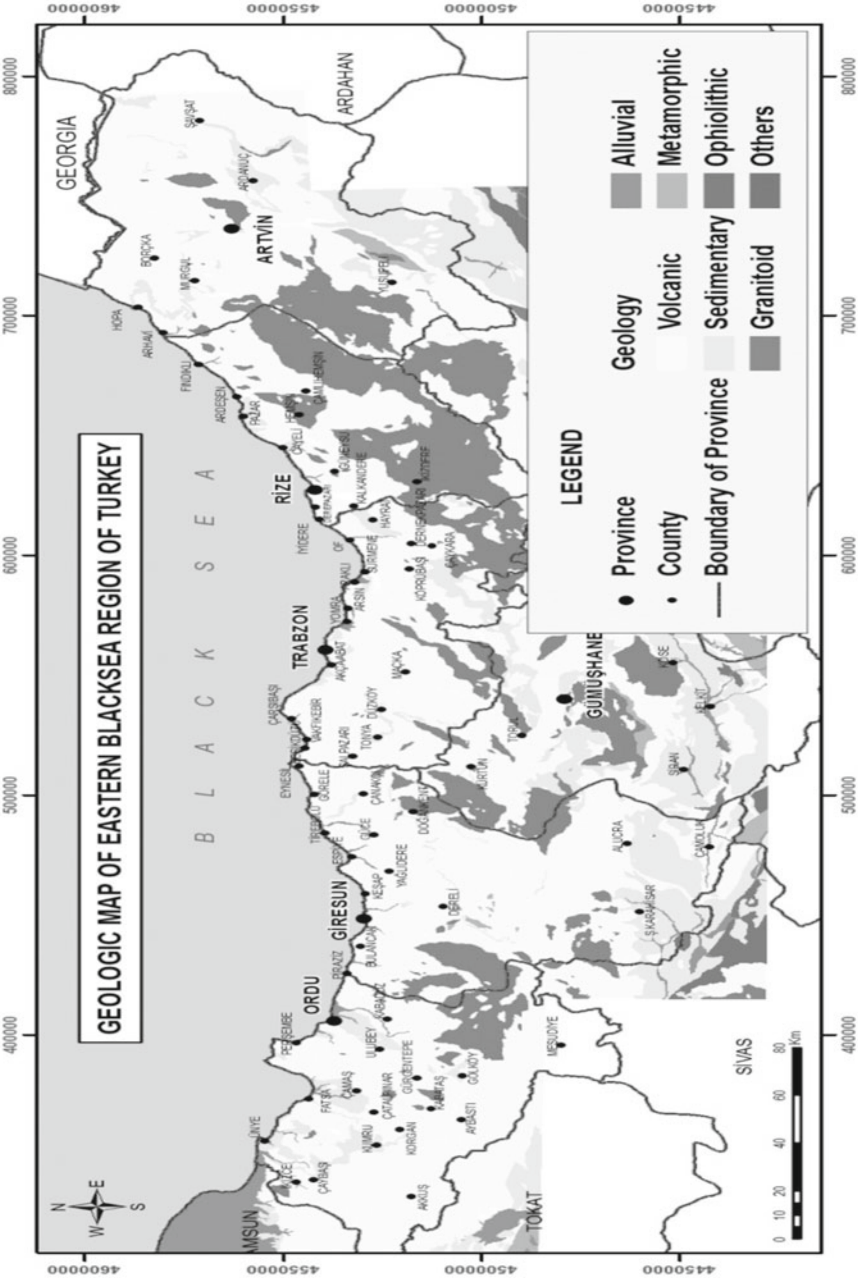


**Figure 4.** Geologic map of Eastern Black Sea region of Turkey.

Figure 5 demonstrates the radioactive value maps of gamma dose, uranium (U-238), thorium (Th-232) and cesium (Cs-137), each produced through the kriging method.

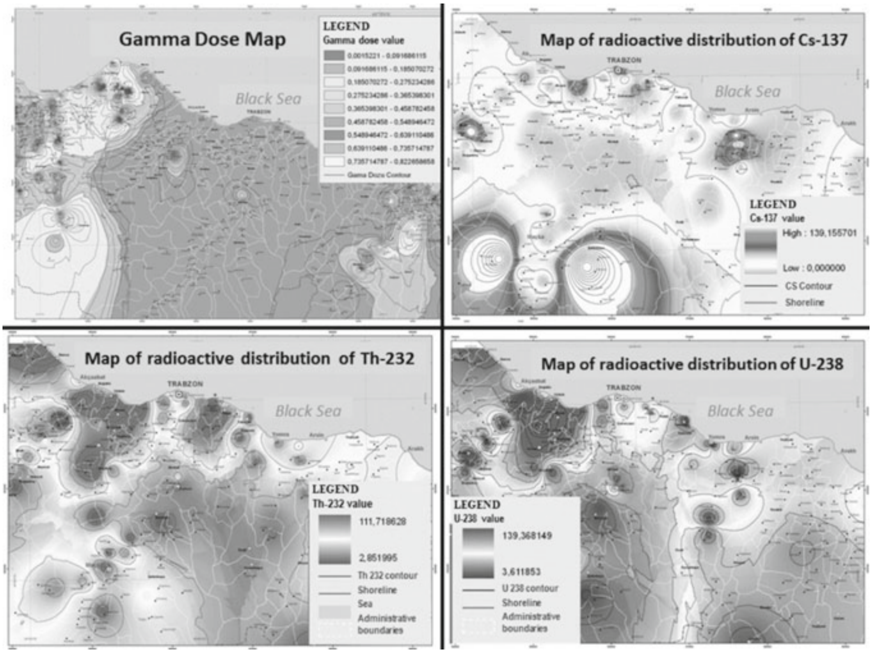


**Figure 5.** Maps of radioactivity in Trabzon Province of Turkey.

### *Water Analysis Data*

Water samples were taken from the water supply networks fed by different sources in the area and subjected to necessary chemical analyses to create the water assessment map of the Eastern Black Sea region of Turkey. Preliminary examinations were performed to identify the carcinogenic elements, such as As, Sb, Be, Cd, Co, Cr, Hg, Ni, Pb, Ve, Se, Te, Tl, V, Ba, Sr, Cu, Bi and Mo (Dissanayake and Changrajith, 1999), and sample collection stations were identified. In total, 574 water samples, defined with a 95% confidence level and 10% limit of error, were collected from the region, thereby enabling the investigation of a correlation between heavy metal data and cancer cases.

Relevant chemical analyses were performed on the collected water samples. In the evaluation of the analysis results, the international water quality standards defined by the World Health Organization (WHO) were used. Analysis results were added to the database, and the locations of the samples were represented on the map. This database was then integrated with the cancer-based geospatial database. Heavy metal analysis maps were produced with these results using spatial analyses and statistical map presentation techniques. These maps enabled the statistical examination of the correlation between all heavy metal data and cancer incidence in the administrative units.

## Integration of Spatial Data

All of the spatially-oriented maps and relevant databases produced throughout the study were integrated in the common geographical reference system using a geodatabase created in a GIS environment, and all spatial and geostatistical analyses were performed on this geodatabase.

To ensure more flexible management of the data that form the basis for spatial analysis, grid representations with dimensions of 100 × 100 m were produced for common use throughout the region. Previously created geospatial data layers were overlaid with these grid areas, guaranteeing the uniform use of pixels in this unique system. Figure 6 demonstrates spatially the most general version of the geospatial data layers produced and used in the study. In conclusion, all geospatial data layers were combined in a geodatabase, and the required spatial analyses were conducted using the integrated approach.

One of the important problems encountered in the analysis of GIS-based cancer cases is that the total number of cases, rather than their point-source distribution, was considered for each administrative unit centre because the cases were not fully attached to a meaningful address. Each case was represented as a point on the administrative unit centre, according to the specified administrative unit code, but for most spatial overlay analysis, a polygon-based data layer was needed, rather than a point-based one. To eliminate this problem, by considering the population data of the administrative

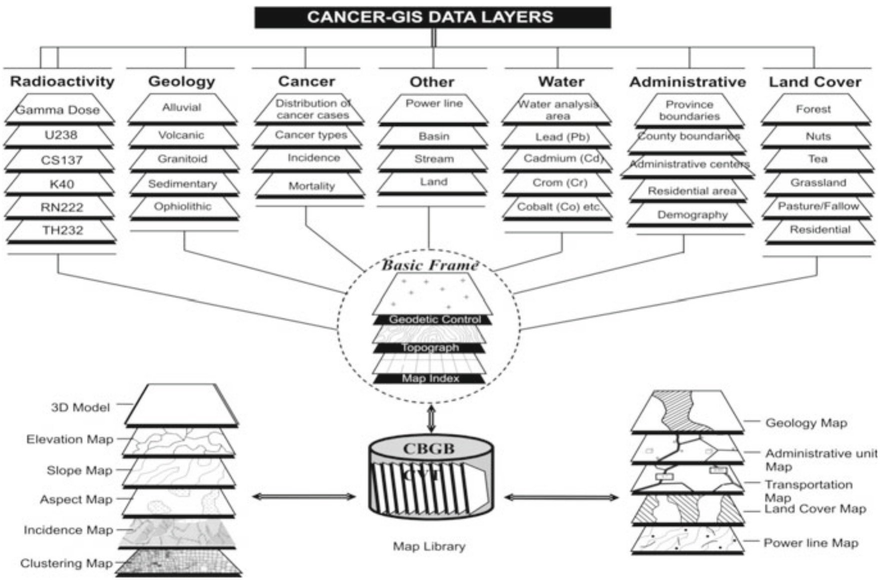


**Figure 6.** Integration of geospatial data layers for a cancer-based GIS.

centres, a polygon-based data layer including detailed data about cancer cases was produced through the application of "buffer" analysis for the spatial representation of administrative units. Most spatial overlay activities were performed with this data layer. This approach prevented unnecessary processes and time loss in GIS.

## Mapping Process for Cancer Cases

The cancer datasets collected in the study and all other required spatial data were incorporated into the geodatabases. Then, various thematic maps were produced through the data presentation opportunities provided by GIS in the scope of the cancer-based Geospatial Database (GDB).

In this study, the spatial distribution of the cancer cases observed in the Eastern Black Sea region of Turkey between 2000 and 2007 was integrated in a geodatabase and shown on base maps using GIS technologies. The cases were represented as points on the administrative units on the map according to the address data obtained. After the cancer cases distribution map was created, incidence rates and the cancer density criteria in each administrative units were calculated and added to the database. Various cancer density maps that depict the cancer densities in the administrative units in the region were produced drawing on the incidence rate data.

In the production of cancer maps, incidence rates indicated the density of cancer in administrative units. The map of distribution of cancer cases observed in the Eastern Black Sea region between 2000 and 2007 was produced in the form of a thematic map presentation, and the map of incidence rates in administrative units was produced using the proportional symbol mapping techniques. In these maps, the representations of cancer density were symbolized by scaling proportional symbols calculated by the incidence values. This chapter includes only one sample map depicting cancer densities in the administrative units produced using the geostatistical method. This cancer density map, shown in Fig. 7, was produced using the kriging interpolation method based on the cancer incidence values.

## Statistical Methods

Although the cancer density rates in administrative units were assessed statistically, only the cancer incidence rate, standardized cancer incidence rate or specific cancer incidence rate was used.

Incidence is defined as the number of new cases of a disease or a health event that occur in a specified time period (Stewart, 2002). Incidence rate indicates the number of new cases within a given time period (i.e. in a year), in a society, the rate of which is known.

Standardization is necessary when comparing two or more societies or communities, the differing basic characteristics (e.g., age, race and socio-economic status) of which influence their respective risks of disease (Esteve

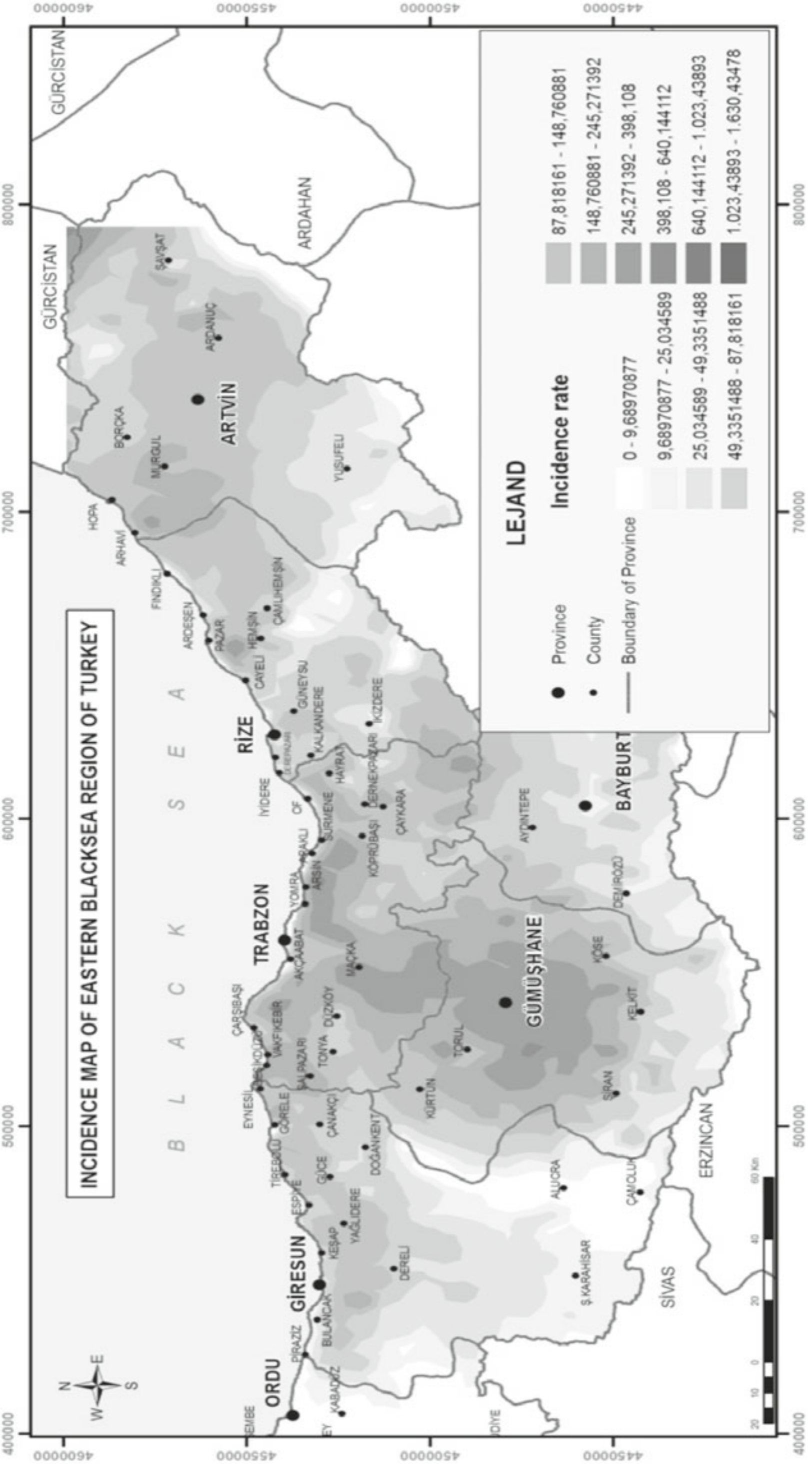


**Figure 7.** The incidence distribution map of Eastern Black Sea region of Turkey.

et al., 1994). The standardized cancer incidence rate refers to the application of common or homogenous characteristics such as age, gender or disease group among different cancer incidence data to enable comparison.

After the incidence densities in the administrative units were calculated, kriging geostatistical analysis method was used to map these densities on geography. In this study, cancer densities were shown on the map of the region in the raster format, using the kriging method. Cancer cluster areas were defined through the Kernel density analysis.

To examine the correlations between cancer frequency and density in the administrative units and the environmental carcinogenic factors, all data were assessed in an integrated style in the GIS environment through spatial analysis and investigations. Relationships between the possible carcinogenic factor targets for investigation and the cancer frequency in residential areas were assessed using the necessary statistical analyses. The Pearson chi-square statistical analysis was used to investigate one-to-one or one-to-many correlations, and other statistical analysis methods, such as the Independent Samples t-test and linear regression, were used in the hypothesis test of bilateral correlations and the analysis of correlations between multifactor environmental causes and cancer frequency, respectively. Statistical methods differed with respect to the content of the hypothesis constructed between each environmental factor and cancer frequencies.

## Examining the Association between Environmental Factors and Cancer

To explore the cancer cases and environmental carcinogenic factors, various spatially based examinations were performed, based on the cancer-based GDB. The cancer data were subjected to overlay analyses in either separate or integrated ways with layers including regional environmental data such as topography, geological structure, water, land cover and radioactivity. The results were then analyzed statistically.

The spatial and statistical analyses in this study tested whether a correlation exists between cancer types and aspect, land cover, geological structure and radioactivity. The chemical analysis results of the heavy metals found in the water samples collected from the administrative units in the region were assessed and represented on maps, and their relationships with the cancer frequencies were tested through geostatistical analyses.

Correlations between cancer cases observed in administrative units or cancer frequency and the environmental factors were considered separately and assessed both geospatially and statistically.

This model allows the examination and statistical assessment of numerous hypotheses regarding environmental factors. However, this book chapter focussed on only one case study. To explore its uses, a sample hypothesis was developed to examine the correlation between the geological structure and the types of cancer, and the necessary spatial examinations and statistical evaluations were carried out.

### Examination of the Correlation between the Geological Structure and Types of Cancer

To examine the correlation between the region's geological structure and types of cancer, spatially-based statistical analyses were performed. With the help of the spatial examinations carried out using the Eastern Black Sea region geological map and the map of the point distribution of the administrative units, the number of cancer cases encountered depending on the geological structure were categorized by cancer type. The Pearson chi-square test was used to identify any correlation between the land's geological structure and types of cancer. The data were classified and arranged for assessment by statistical software.

Pearson chi-square test was employed through a statistics software in order to statistically examine whether there exists a correlation between types of cancer and the land's geological structure. The statistical analysis used classes of seven rock types and ten types of cancer (lung/bronchial/larynx, skin, leukemia, breast, stomach, colon/rectum, bladder, prostate, thyroid and other types of cancer). The impact of elevation on cancer types was significant according to the results of the Pearson chi-square test ($\chi^2 = 82.378$, SD = 45, $p = 0.001$). According to the results of the statistical analyses, 10.3% of 15,223 cancer cases were observed in sedimentary rock type, 83.1% in volcanic, 2.7% in granitoid, 2.3% in alluvial, 0.1% in metamorphic and ophiolitic mixture and 1.4% in other rock types.

In determining the correlation between types of cancer and rock types, examining the environments that cause this correlation is necessary. Adjusted residuals were used for this purpose. An adjusted residual greater or equal to two is significant for the correlation between two categories of data (rock type and type of cancer). Based on the results of the statistical analysis, stomach and breast cancers were encountered more in areas where the rock type is volcanic, and stomach cancer was observed more in areas where the rock type is granitoid (adjusted $R^2 \geq |2|$).

## Conclusion

Accurately analyzing diseases that threaten public health is necessary to determine prevention and control strategies. To this end, the spatial distribution of the disease, its density areas and relevant statistical dimensions should be examined. Obtaining patient address information and medical history enables the investigation of the health-location relationship. Today, the monitoring of the spatial distribution of diseases uses GIS to produce information systems based on location and to conduct various spatial and statistical examinations. These systems allow for the simultaneous consideration of health and location, and these systems increase the flexibility and comprehensiveness to demonstrate the regional differences in terms of health and the correlation between a disease and its spatial distribution, land cover, land use, geological structure and elevation.

The frequency of cancer cases in administrative units was spatially compared with population, and its various relationships with environmental factors were investigated through geospatial analyses and statistical examinations. The study aimed to bring together the variety of studies oriented toward cancer epidemiology and address them with an integrated approach. Regions and locations in need of more detailed studies can be determined, and more specifically, environmental exposure studies focussing on a certain type of cancer can utilize these locations. In conclusion, GIS enabled the simultaneous consideration of many environmental factors and played a significant role in this research.

This study demonstrated the effective use of GIS in cancer prevention and control programmes through the spatial representation of cancer case distributions. Performing numerous epidemiological statistical analyses and examinations using the digital cancer maps was enabled by GIS. Visual representation of cancer incidence became possible through these maps, and the important data became available for decision-makers and public health researchers.

The use of GIS in public health management and practice has provided a descriptive and analytic tool that increases the understanding of geographic patterns, spatial relationships and related phenomena. GIS can also utilize mathematical modelling to predict spatial trends and future occurrences (Thrall, 1999). Recent studies have been more concerned with the production of cancer atlases, and studies investigating the relationship between environmental health risks and cancer have covered smaller areas. Future studies on cancer mapping may demonstrate the differences between countries or even continents rather than small areas, and more sophisticated mathematical and statistical algorithms will enable the modelling of the complex relationship between the environmental exposures and human health.

All environmental exposures including pollution discharge sites, underground storage tanks, hazardous waste sites, water discharge pipes and plumes, radioactive elements and others, can also be monitored and analyzed using GIS, and the relationship between human health and these environmental exposures can be examined. GIS will also enable researchers to share the latest analyzed data. The ability to publish results immediately with the statistical outputs in GIS will strengthen health research and enhance information sharing.

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