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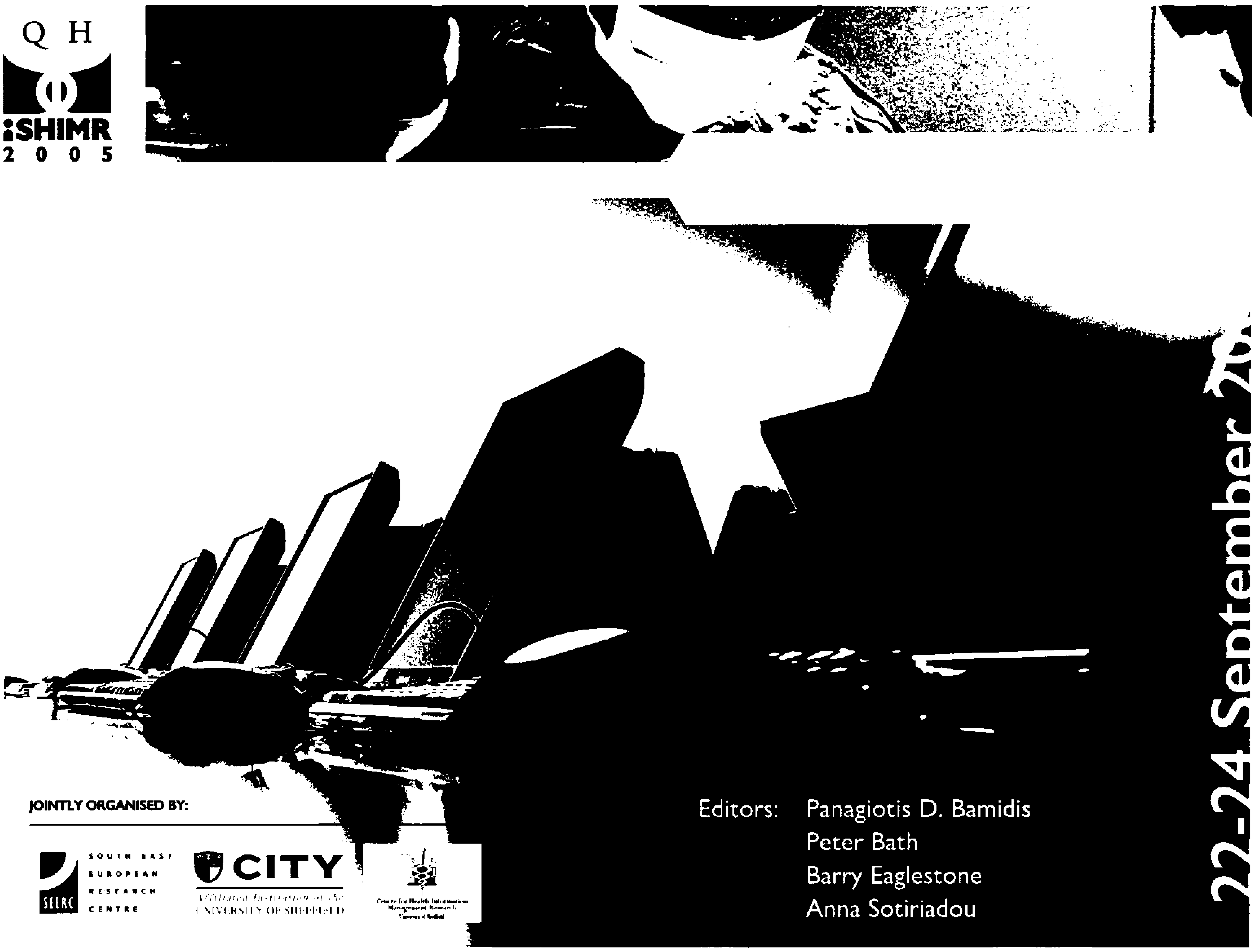

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A Geographical Database for the Control of Leishmaniasis: the Case of Greater Athens, Greece.

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The aim of this paper is to present some research hypotheses and empirical evidence concerning the geographical distribution and spread of leishmaniasis in Greece and particularly in the Greater Athens region, through spatial analysis in a GIS environment. Greece is the WHO Collaborating Center for research and training in Mediterranean zoonoses[1]. Research for leishmaniasis in Greece has indicated that most of the incidents of the disease are concentrated in the Greater Athens region. The results presented in this paper are based on a research project which is currently carried out by the Technological Educational Institution of Athens[2] in collaboration with the University of Crete and the Aristotle University of Thessalonica. The main hypothesis in this paper is that there is a geographical dimension in the diffusion of the disease of leishmaniasis in the Greater Athens region. This dimension includes several environmental factors as indicated in the relevant literature (i.e. elevation, vegetation, meteorological factors, the presence of quarries and dump sites and socioeconomic factors), but also the hypothesis that the incidents of the disease are clustered in the foothills of mountains which surround the Athens Basin, while they tend to follow the urban expansions towards these mountains. The available data concern incidents of leishmaniasis in the years 1961-2004. The incidents are mapped as well as the factors which are believed to affect the spatial distribution of the disease. The results are combined in a geographical database so that the possible interplay among them can be detected employing methods of spatial analysis. The preliminary results indicate that the above stated hypothesis is supported with some qualifications regarding mostly the elevation parameter.

Keywords
Disease risk mapping, geographical information system (GIS), leishmaniasis, spatial analysis

1. Environmental factors affecting the spread of Leishmaniasis

According to Diggle [1], "environmental epidemiology, defined as the study of the spatial or spatiotemporal distribution of diseases in relation to possible environmental factors, constitutes an important tool for better understanding of the dynamics of parasitic infections and the development of suitable control and prevention strategies". Leishmaniasis, as indicated in the relevant literature, is a vector-borne disease highly influenced by environmental factors.

A study made by B. Bucheton et al. [2] evaluated the principal risk factors for Visceral Leishmaniasis (VL) during an outbreak in a village of eastern Sudan. It was carried out over the whole outbreak, from 1996 to 1999. The risk of developing VL was analysed in relation to environmental, economic, ethnic and familial factors.

According to the study, the main factors that are expected to play an important role in the parasite–human interaction are exposure, parasite "virulence" and host resistance factors. Environmental factors such as the presence of cows and neems in the households had significant effects on the increase/decrease of the exposure to the parasite and on the distribution of VL cases in the study area. More specifically, the environmental factors found to be associated with an increased risk of VL in the univariate analysis are:

1. the presence of dogs, cows, Balanites trees and a high density of trees.
2. host factors (economic status, daily activity, age, gender and ethnic origin)

The results of the paper suggest that environmental factors that affect sandfly ecology, human activities that increase exposure to sandflies and the presence of other animals permissive to the Leishmania life cycle, play critical roles in the development of the human disease. Poor economic conditions have also been shown to increase the risk of VL.

J.A. Patz et al. [3] state that ecological disturbances influence the emergence and spread of zoonotic parasitic diseases such as Leishmaniasis. Each environmental change, whether occurring through human intervention or as a natural phenomenon, alters the ecological balance and state in which the disease vectors, hosts and parasites breed, develop and transmit the disease. According to the study, such ecological disturbances include the following:

- deforestation
- replacement of forests with crop farming ranching, small animals
- bodies of water in disrupted areas
- human movement
- vector competence
- zoophyllic to anthropophyllic orientation
- water control projects
- road construction
- climate and parasitic disease
- temperature and rainfall
- El Nino.

Another study used data on the presence and absence of Phlebotomus (P) orientalis from 44 collecting sites across central Sudan. A logistic regression model estimated the probability of the presence of P. orientalis at each collecting site as a function of climatic and environmental variables. The environmental variables employed were rainfall, temperature, altitude, soil type, a Normalised Difference Vegetation Index and Land Surface Temperature.

The results show that the mean annual maximum daily temperature and the soil type are the most important ecological determinants of the vector distribution. On a smaller scale, density-independent factors, such as microclimate, further limit the distribution of the vector species [4].

Phlebotomine Sandflies play a vital role in the transmission of visceral, cutaneous and mucocutaneous leishmaniasis. Observations were made on the adaptability of different phlebotomine species to arid conditions of temperature and relative humidity.

Phlebotomine prevalence recorded during the studies showed a definite correlation with temperature and a moderately negative correlation with relative humidity. The high prevalence of females in higher temperatures indicates their ability to withstand these temperatures and can be considered a matter of epidemiological importance as it may aid the transmission of cutaneous leishmaniasis in arid conditions [5].

The main environmental factors which are being monitored by the analysis of the satellite data are rainfall, humidity, temperature and environmental "greenness". Spatial data defines the climatic and environmental factors affecting the vector population dynamics, and hence the pathogen transmission potential can be monitored [6].

The environmental variables which were depicted in a study of 190 villages in Gedaref State included rainfall, vegetation status, soil type, altitude, distance from river, topography, wetness indexes and average rainfall estimates. It has been found that average rainfall and the altitude were the best predictors of VL incidence [7].

The Leishmaniases are also shown to be related to urbanisation and migration of non-immune people to endemic areas: A study made in a municipality located in Southeast Brazil, investigates the spacio-temporal patterns of the disease and environmental risk factors from 1966 to 1996. The conclusions suggest that environmental modifications in the vicinity of households over time and accumulation of susceptible individuals are factors that affect the rate variability. The incidence rates of American Cutaneous Leishmaniasis (ACL) were found to be independently associated with rural areas, higher proportion of exposed garbage and areas lacking sanitary installations. The paper also states that environmental modifications in urban areas would result in a decreased exposure to several factors related to the transmission of the disease. In the case of rural areas, a continuous or increased exposure of humans within the sylvan environment could be able to maintain the transmission of the disease [8].

The construction of dams is considered to be an important environmental modification, since it can change the temperature and humidity of the soil and vegetation, which may in turn result in changes in the composition and density of sandfly species as well as changes in populations of rodent species [9].

A study made by Papadopoulos B., Tselentis Y. [10], in the Athens region investigated the main distribution patterns of the sandfly species responsible for the spread of Leishmaniasis in the study area. The environmental factors that account for differences in the distribution of sandfly species and therefore the spread of the disease were the extensive construction and expansion of the city to the foothills of the surrounding mountains and hills, temperature, rainfall and the existence of quarries.

A consequent study conducted at the same region stated that the high distribution of sandflies in the vicinity of quarries can be explained by the fact that these sites are a mass of cracks, crevices and small or large caves which shelter considerable populations of rodents and, during the summer, stray dogs. Since the dog is the principal reservoir host of Leishmania infantum, it seems clear that the quarries must be significant foci for canine and, by extension, human VL [11].

In order to determine whether the aforementioned environmental factors affect the emergence or/and the spread of the Leishmaniasis, statistical and spatial methods are used for the investigation of such associations. The present paper focuses on the bibliographic reviews which use geographical information systems (GIS) as a mean of investigating possible associations.

Thomson et al. [12] used a raster-based geographical information system to create an initial risk map which indicates the area where the vector might occur. The final risk map was refined using the rainfall-based boundaries of the distribution of Acacia-Balanites woodland which is known to be associated with the distribution of the disease vector. The final result is the definition of the ecological boundaries of the vector of the Visceral Leishmaniasis and the production of a risk map for the disease.

Also, remote sensing approaches and spatial information technologies are used for the control of the arthropod vectors of disease. Integrating the temporal and spatial processes can be a powerful system for assessing disease vector dynamics in relation to disease patterns and the impact of control measures [13].

Moreover, GIS were used to extract and map regression results for environmental variables in the Gedaref State study [14]. VL incidence in each village was calculated from hospital records. By use of multivariate logistic and linear regression analyses, models were developed to determine which environmental factors explain variability in VL presence and incidence. The resulting models were mapped by GIS software predicting both VL presence or absence and incidence at any locality in Gedaref State.

In the Southeast Brazil study [15], a Poisson regression model was used to identify environmental factors related to rate variability.

Concluding, the main environmental factors stated in the literature are listed below:

- Temperature
- Soil type
- Ecological disturbances
- Rainfall
- Altitude
- Urbanization
- Migration of non-immune people to endemic areas
- Presence of quarries
- Relative humidity
- Construction of dams
- Socioeconomic factors
- Vegetation Density

In order to investigate the possible association between the disease and the environmental factors, we need to import and organise into a GIS, environmental data which accurately represent the factors which have been shown to affect the spread of Leishmaniasis.

2. Leishmaniasis in Greece

Human incidents of leishmaniasis in Greece have been recorded since 1961 by the Ministry of Health and refer to the age, sex, address of the patients, hospital of treatment and the type of leishmaniasis. Most of the reported cases concern visceral leishmaniasis and there is no indication as to whether they were fatal or not. In Greece, the greater Athens region is one of the endemic areas of visceral leishmaniasis.

Research on leishmaniasis has been carried out by the Faculty of Medicine of the University of Crete. In 1992 a survey was carried out in the Athens Region and sandflies were collected from May to October, which is considered to be the season of activity of adult sandflies [16]. The survey was accompanied by case studies, i.e., interviews with patients, in an effort to determine the way the disease was transmitted. The results gave indications that sandflies and patients are concentrated in the foothills of the mountains surrounding the Athens Basin, while the main environmental factors accounting for the spread of the disease were temperature, rainfall and the existence of quarries.

In this paper the preliminary results of an on-going research on leishmaniasis are presented. The focus of this research is the analysis of incidents using GIS technology, because the spatial dimension is considered to be of great importance for the distribution and spread of leishmaniasis. A number of environmental factors which were presented in the previous section and appear in the relevant literature, i.e., elevation, meteorological factors, vegetation, socioeconomic factors, the existence of quarries and dump sites, are examined. However, based on the empirical evidence of the research carried out in 1992, the present research additionally examines the hypothesis that leishmaniasis presents higher frequency in the foothills of the mountains surrounding the Athens Basin, namely Ymittos, Penteli and Parnitha, and also around several hills in the region. In the later stages of this research the importance of the above mentioned factors will be tested using spatial statistics integrated in the GIS technology, in an effort to generate a spatial model for the surveillance of the disease. In addition, a new survey of sandflies in the Greater Athens Region is being carried out for the year 2005 and the results will be compared to those of the 1992 survey, and will be correlated with the environmental factors.

The data, which are presented in maps in this paper, include those incidents of leishmaniasis for which geographic reference is available. For the period 1961-2004 a total of 1341 incidents were reported. However, for some of these years the address of the patient has not been recorded, even at municipality level[3]. In that respect, although data for these years are useful for the study of the temporal trend of the disease, they are not suitable for studying the spatial patterns of the disease and are considered missing in a GIS based analysis. A total of 209 cases fall in this category. In addition, in more than half of the cases the exact address (street and number) is not included and as a result the possibilities of analysing point patterns are limited to only 381 cases. For the reduction of these problems with data collection, improved methods of recording the incidents are required, so that spatial analysis can be carried out and point out risk areas in which the surveillance of the disease will be more effective.

A description of the data employed is presented below. In Figure 1 a temporal analysis for 1341 cases is shown which indicates that there were peaks of the reported incidents in the years 1976, 1986, 1993, 1994 and 2000 with approximately 50 cases per year, while the average for the whole time period is 30 cases per year. Consequently, the data present time periodicity as it has been stated in other studies (Machado-Coelho et al., 1999).

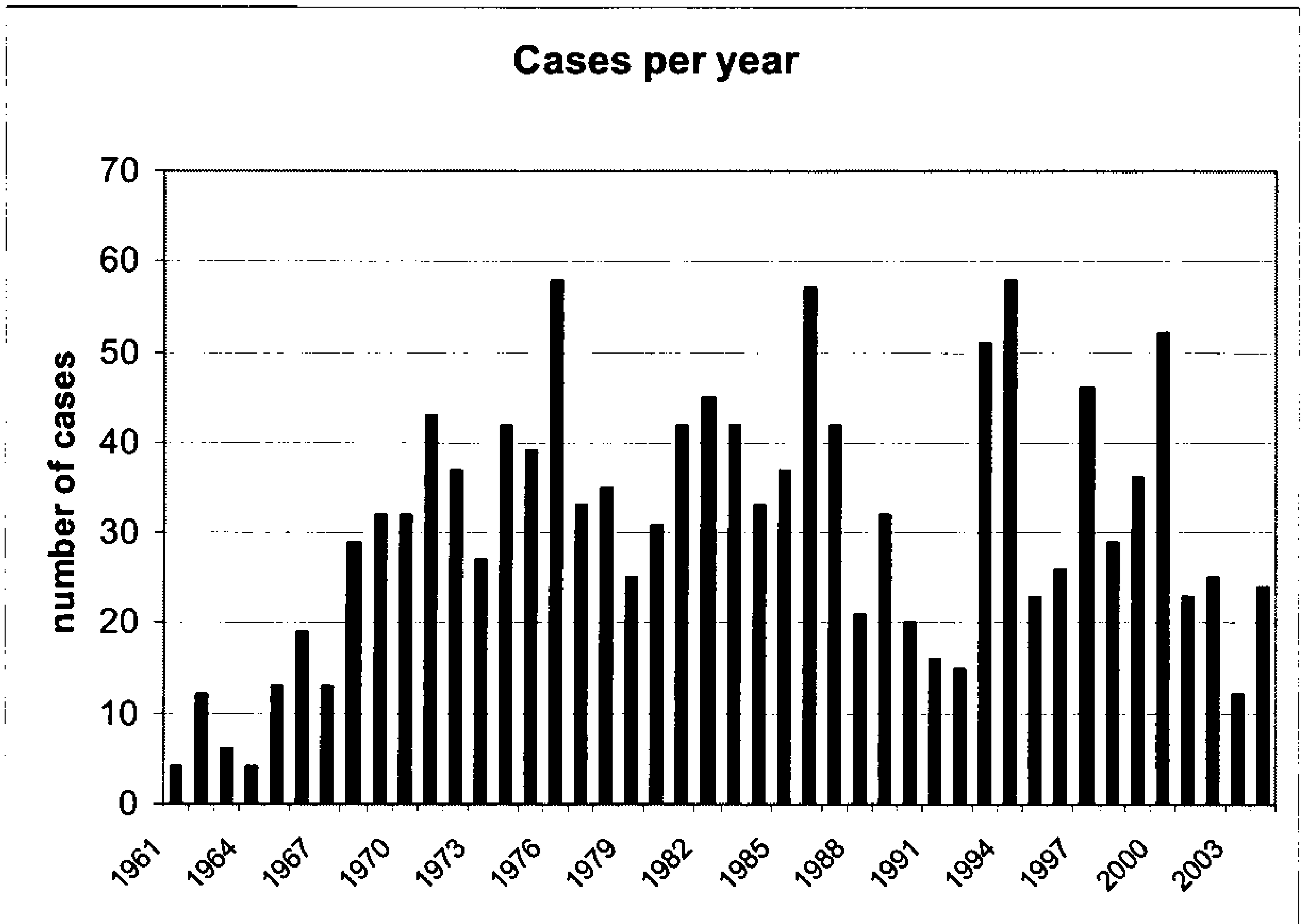

Figure 1 Results from temporal analysis for 1341 leishmaniasis cases in grater Athens region

Concerning the distribution by sex, the results for 1185 cases indicate that the disease has a higher effect on males (59% males and 41% females). This can be explained by differences in daily activity.

The age distribution of patients in 5-year age groups for 1248 cases is presented in Figure 2. As is well known, most of the patients are children. The mean of the distribution is 19.22 years, the minimum is 0 (four cases under the age of one) and the maximum is the age of 93 (one case in the whole time period). The age group 0-5 years accounts for 40.9% of the cases and the 0-10 age group for 53.5%, thus more than 50% of the cases concern children under the age of 10. As figure 2 indicates, there is an inverse relationship between age and cases.

age groups

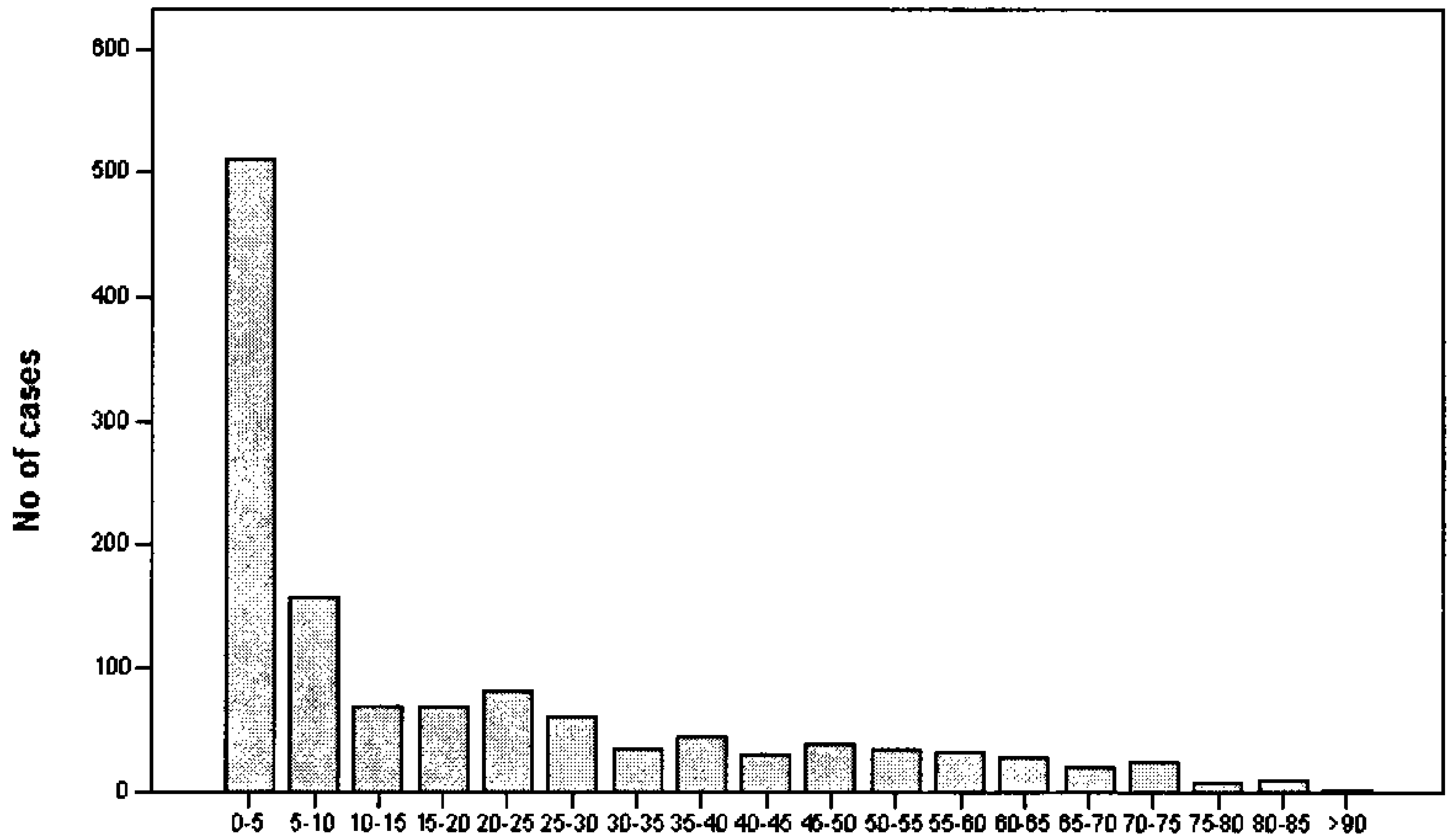

Figure 2 Age distribution of patients in 5-year age groups for 1248 cases in grater Athens region

3. Materials and Methods

The recent increase of computing power has facilitated the rapid growth of information systems for vector ecologists and controllers of vector-borne diseases. Improvements in computer hardware have supported developments in software for analysing and mapping vector distribution and abundance in space and time, allowing changes to be correlated with environmental and demographic variables, by means of Global Positioning Systems (GPS), Remote Sensing (RS) and GIS. All these technologies are based on the physical position of any one observation known in relation to all other observations. [17].

These systems offer great opportunities to the user, allowing alternative possibilities of spatial analysis, where the geographic distribution of disease comprises a part of the problem [18]. Especially, GIS, as a powerful and integrated set of tools and methodologies for collection, storing, retrieving, analysing and displaying spatial as well as non spatial (attribute) data, improve the development of processes for study and research, regarding parasitic diseases which are highly conditioned by environmental risk factors [19]. Because of their abilities for analysis and decision-making, GIS can be considered to be the modern view for the management of information that associates the human health with both time and space in order to give to the specialist the ability to design and carry out projects for continuously monitoring of the pattern of the diseases dynamics [20].

Having all the above in mind, as well as the results of an extensive survey on the sandfly population[4] carried out in Athens, Piraeus and their suburbs in 1992[5], it was decided in this research to use the above mentioned technologies (GPS, RS and GIS) in order to investigate how the disease of leishmaniasis spread in this specific place so as to substantiate the environmental factors corresponding to this diffusion both in time and space. The primary conception for this research was to "reconstruct" the above mentioned survey's results in a GIS in order to define the high risk areas for the disease of leishmaniasis as they were in 1992, focusing on the same study area. In this way, it is believed that the 1992 survey might be considered a "starting control point" for measures and calibrations concerning the influence of spatiotemporal data related to the spread of the disease. This ability allows the comparisons between contemporary, past and, of course, forthcoming data using GIS techniques.

The following significant points discussed in the report of the above mentioned survey have been useful for the current research; namely, they constitute a valuable guide for the definition of the environmental factors as additional layers of information for the combination between geographical space, time and the disease endemicity:

- In Greece, the greater Athens region is one of the endemic areas of VL.
- The extensive construction and expansion of the city to the foothills of the surrounding mountains and the hills within its limits, due to the rapidly increasing population, has resulted in a highly modified landscape in the last 45 years, which undoubtedly has changed the distribution of sandflies.
- The statistics of the Greek Ministry of Health for the period 1961-1991 showed that 57,9% of all human VL cases in Greece had originated in Athens, Piraeus and their suburbs.
- A retrospective study contacted in the area under discussion in the 70's has showed an increase of the clinical VL cases since the 1960's and that 75% of the infected persons were living on or near the slopes of the mountains surrounding the Athens Basin and its hills.
- Many of the cases occurred in the vicinity of quarries and dumps.
- The risk is greater on the outskirts of the city and less in the central part where urbanisation and pollution have created unfavourable conditions for the survival of sandflies.

3.1 The study area

Since a part of the present research is based on the results of the earlier study of sandflies in the Greater Athens Region held in 1992, the definition of the study area for this research was based on the way that the above study had defined it.

This means that the altitude, the present extend of the urban areas, and the location of quarries and dumps consisted the main geographical factors in order to determine the area of the present study. This area includes sixty municipalities of the prefecture of Attica, it is an urban area of 448500 sq km, and it is situated to the west of Mount Ymittos (1026 m.), the east of Mount Egaleo (452 m.), the south-west of Mount Penteli (1108 m.), the south-east of Mount Parnis (1413 m.) and the north of the Gulf of Saronikos (Figure 3).

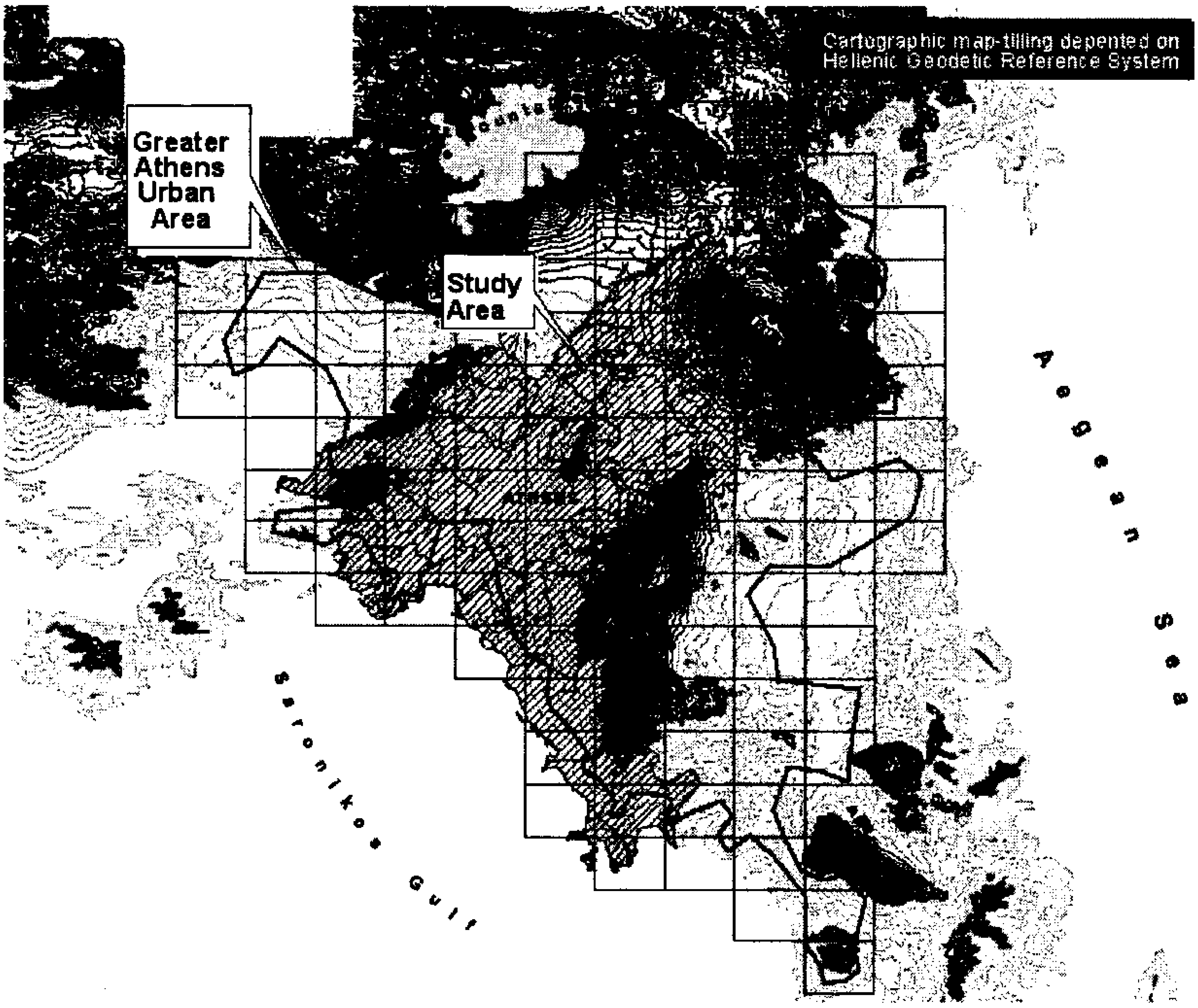

Figure 3: The study area of the research

It is a highly build-up area with a large population. During the last years, due to intensive urbanisation, most of the suburbs which are near the mountains surrounding the city have been expanded towards the slopes (Figure 4).

Figure 4 Most of the suburbs of the city of Athens which are near the mountains surrounding the city have been expanded towards the slopes.

The existence of many quarries and dumps, which in several cases are found very close or adjacent to the urban areas, should also be noted (figures 5a and 5b).

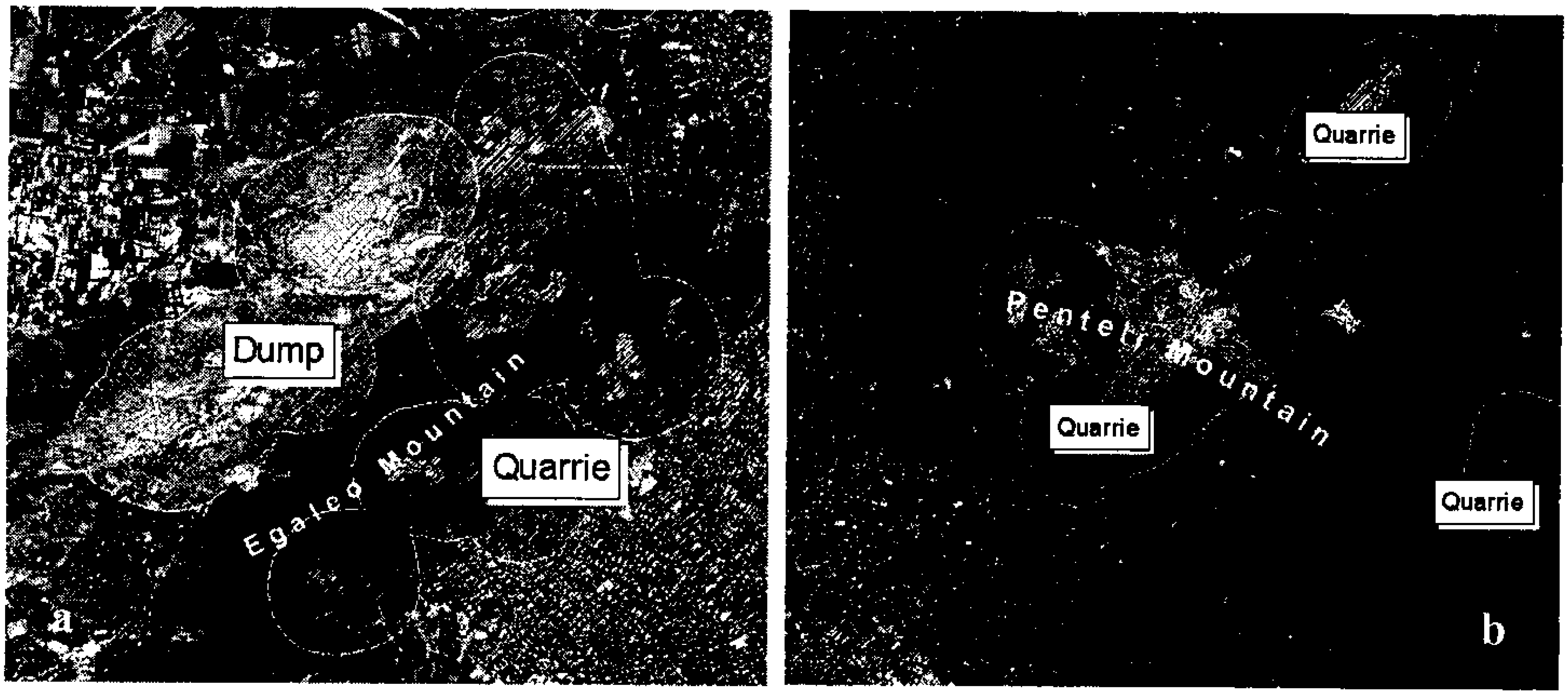

Figure 5: Many quarries and dumps, in several cases are found very close or adjacent to the urban areas of the suburbs of the city of Athens.

3.2 Data Collection

Geographical and descriptive data obtained from several Ministries (Environment and Public Works, Food and Agriculture Development, Health and Public Protection, etc.) and Public Organizations (Hellenic Military Geographical Service <HMGS>, National Statistical Service <NSS>, National Meteorological Service <NMS>, Athens' Company for Water Supply and Drainage, etc.) and updated by the Laboratory of GeoInformation of the department of Topography of the T.E.I. of Athens, were collected for the purposes of this research. Also, the results from the 1992 survey conducted by the Laboratory of Bacteriology, Parasitology, Zoonoses and Geographic Medicine of the University of Crete, as well as special data concerning the human VL and CL cases in a forty-five-year period, were made available for the same purposes.

For the concretisation of the geographical database, the platform of ArcGIS 9.0 (ESRI Redlands) was selected. The use of Microsoft Access was selected as a relational database management system, so as to keep the cost of the project in low levels regarding the use of software and the possibility of management of copies of the geographical database from more than one users without expertise in relational databases management.

3.3 Data description

Spatially-referenced data which correspond to the environmental factors that have influenced the diffusion of the disease are used in this study to establish the needed layers of geographical information. Moreover, non-spatially referenced data (tabulated time-series) are used to relate the tabulated information to the above layers and expand the geographical database for the purposes of the research.

3.3.1 Spatially referenced data

As far as the spatially referenced data are concerned, three different formats were used: Vector, Raster and Grid data.

The raster models regard the space as a total of distinguishable elementary pixels. In the extent of each pixel, it is assumed that the observed value of a phenomenon is specific. Hence the raster models are ideal for the representation of contiguous phenomena as the observed temperature, the altitude, etc. The raster models are represented very easily in the computer as tables of values, while complex calculations with matrix algebra are very easily materialized. The raster data used in this research were of two kinds:

- *Orthophotomaps* on a scale of 1:5000, resolution 2 m., based on the World Geodetic System (WGS'84), following the Greek Grid, and produced for other purposes by the Ministry of Food and Agriculture Development in 1996 and in 2000, and by the Athens' Company for Water Supply and Drainage in 2002, covered the whole study area.
- *Remote Sensed Data* (Panchromatic LANDSAT TM, resolution 30m., based on the WGS'84) on a scale of 1:100,000, and obtained from the Ministry of Environment and Public Works for the purposes of the Corine Land Cover Project in 1990 and 2000, also covered the whole study area (Figure 6).

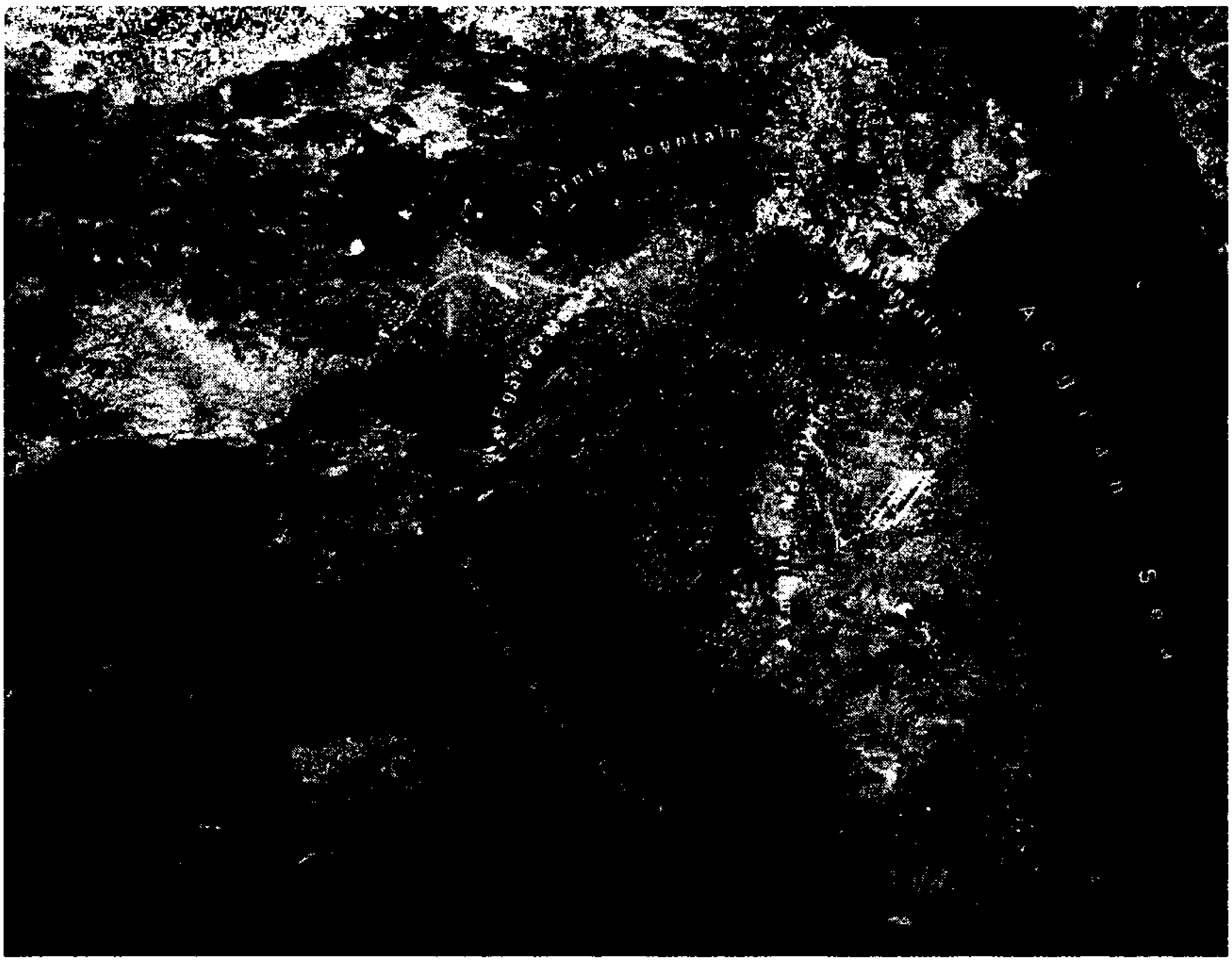

Figure 6: Panchromatic geo-referenced satellite image (LANDSAT TM, year 2000) where the study area is represented.

The vector models are capable of storing the geographic entities with precision and to produce maps of high quality. In the vector models, the geographic entities are depicted with the help of elementary objects, such as point, line and polygon, which are digitally represented as a series of coordinates usually in a two-dimensional space.

In this research, the vector data were organized and processed by the ArcMap and ArcCatalog software that are autonomous applications of the ArcGIS platform. The database was designed according to the Tomlin model[6]. The geographic characteristics were organized in similar totals (datasets) that have a reasonable relationship between them and constitute the thematic layers of the model. Each thematic layer constitutes a class of geographic entities so as to materialize a minimum behavior of entities. The datasets are:

- *Administrative dataset* which has the following thematic layers:

Borders (polygon) that represents the boundaries of Attica derived from the digitization of maps on a scale of 1:50,000 (1990).

OTA50K (polygon) that represents the boundaries of the municipalities derived from the digitization of maps on a scale of 1:50,000 (1996).

Prefectures50K (polygon) that represents the boundaries of the prefectures consisting Attica derived from the digitization of maps on a scale of 1:50,000 (1990).

- *Gazetteer dataset* which has the following thematic layers:

  Place names (point) that represents the toponymies of the center of Athens and its surroundings derived from the digitization of maps on a scale of 1:5,000 and information from road atlases (2004).

  Place names NHMDB (point) that represents the toponymies of the whole prefecture of Attica derived from the National Hydrological and Meteorological database (NHMDB) (1996).

- *Health dataset* which have the following thematic layers:

  Stations (point) that represents the locations (in Cartesian coordinates X, Y, Z) of the sandflies sample collection derived from the measurements of the former survey (1993).

  Leishmaniasis Cases (point) that represents the locations of the infected from the disease humans (1961-2004)[7].

- *Hydrology dataset* which has the following thematic layers:

  Aqueducts (line) that represents the aqueducts derived from the NHMDB (1996).

  Rivers (line) that represents the rivers as they derived from a digital elevation model (DEM) based on hypsometrical information from the NHMDB (1996).

  Wells (point) that represents the drillings derived from the NHMDB (1996).

- *Land cover dataset* which has the following thematic layers:

  Corine (polygon) that represents the land cover on a scale of 1:100,000 derived from E.U. project CORINE LandCover (1994). (Figure 7)

  IdentificationLots (polygon) that represents the land cover on a scale of 1:5,000 derived from the Ministry's of Food and Agriculture Development project called Integrated Administrative Control System (I.A.C.S) (1998-2001).

  LandCover (polygon) that represents the land use on a scale of 1:10,000 derived from the NSS and enriched with information concerning the new infrastructure works (2002).

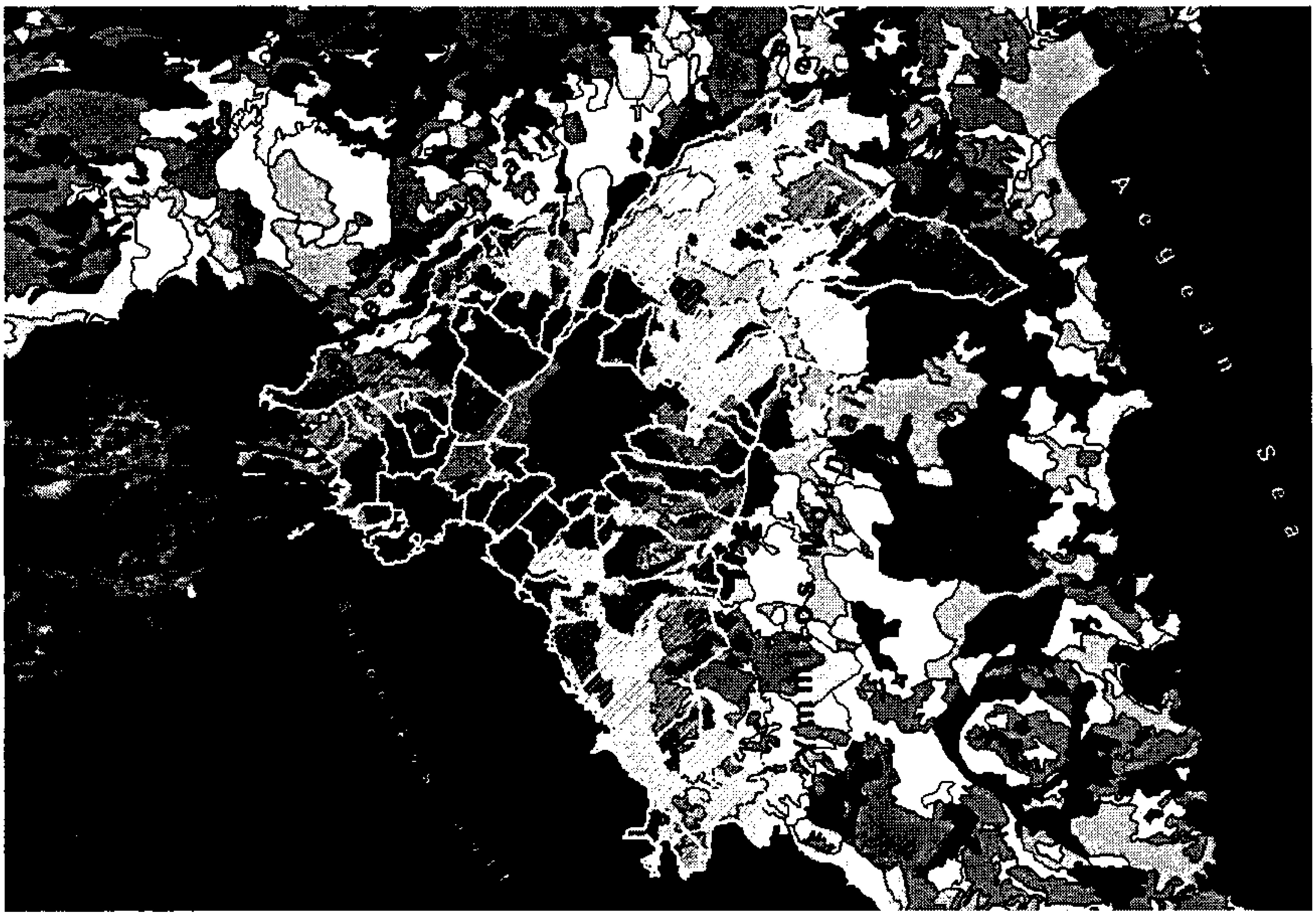

Figure 7: Polygons that represent the land cover according the specifications of the project Corine LandCover Greece, funded by E.U., derived from LANDSAT TM (year 1990).

- *PointsOfInterest dataset* which has the following thematic layers:
  Landmarks (point) that represents the places of important locations of the study area (1990 – 2004) derived from the GeoInformation Laboratory.
- *TillingSchemes dataset* which has the following thematic layers:
  Tiles50K (polygon) that represents the HMGS's map distribution on a scale of 1:50,000 depended on the Hellenic Geodetic Reference System and derived from the GeoInformation Laboratory (1992).
  Tiles5K (polygon) that represents the HMGS's map distribution on a scale of 1:5,000 depended on the Hellenic Geodetic Reference System (HGRS) and derived from the GeoInformation Laboratory (1992).
- *Topography dataset* which has the following thematic layers:
  Contours (line) that represents the contour lines derived from HMGS's maps on a scale of 1:5,000, updated from the GeoInformation Laboratory (1990-1998).
- *Transportation dataset* which has the following thematic layers:
  RailRoadNetworkNHMDB (line) that represents the railway network in Attica prefecture on a scale of 1:50,000, updated from the GeoInformation Laboratory (1998-2002).
  StreetNetwork (line) that represents the street network in Attica prefecture on a scale of 1:5,000, updated from the GeoInformation Laboratory (1998-...).

3.3.2 Non spatially referenced data

The appropriately materialized tables are defined as:

- *NewStations:* The locations of the new survey's stations where sandflies are going to be collected, and whose coordinates are defined by GPS, are tabulated and joined with the spatial table of the layer Stations (at Health dataset). The present research uses about 45 of the 70 locations of the sandflies collection of the 1992 survey and defines other 45 in the boundaries of the study area by using the method of systematic stratified spatial sampling.

- *Sandflies:* The results of the surveys made in 1992 and 2004 are recorded here. Sandflies were collected from a number of stations in the study area, using "sticky-traps". The table also includes the collected number of sandfly species and is joined with the spatial table of the layer Stations (at Health dataset)
- *HumanChar:* The location of residence and characteristics of human VL cases, where time-series of demographic and socioeconomic data are tabulated and joined with the spatial table of LeishmaniasisCases (at Health dataset) in order to associate some of the environmental factors with the endemicity of disease in the study area and to investigate if the socioeconomic parameters affect the disease diffusion.
- *Meteo:* Meteorological time-series information for the study area collected from the NMS is tabulated there. The information will be combined with the distribution of sandflies.

3.4 Data analyzing and mapping

At the first step of data manipulation, analysis and visualization, it became obvious that the results of the former research depicted the problem of the VL diffusion quite accurately.

As it observed after the visualization of the location of the human VL cases for the period 1961-2000, many of them were found near the quarries and the foothills where the urban areas had expanded. However, it should still be examined if the concentration of patients has also been affected by other factors, while the homogeneity of their distribution is not always observed. In Figure 8 below (which presents only a small part of the study area), it can be seen that there is a major concentration around the Tourkovounia Hill, whereas the same cannot be said for the concentration around the Egaleo Mountain.

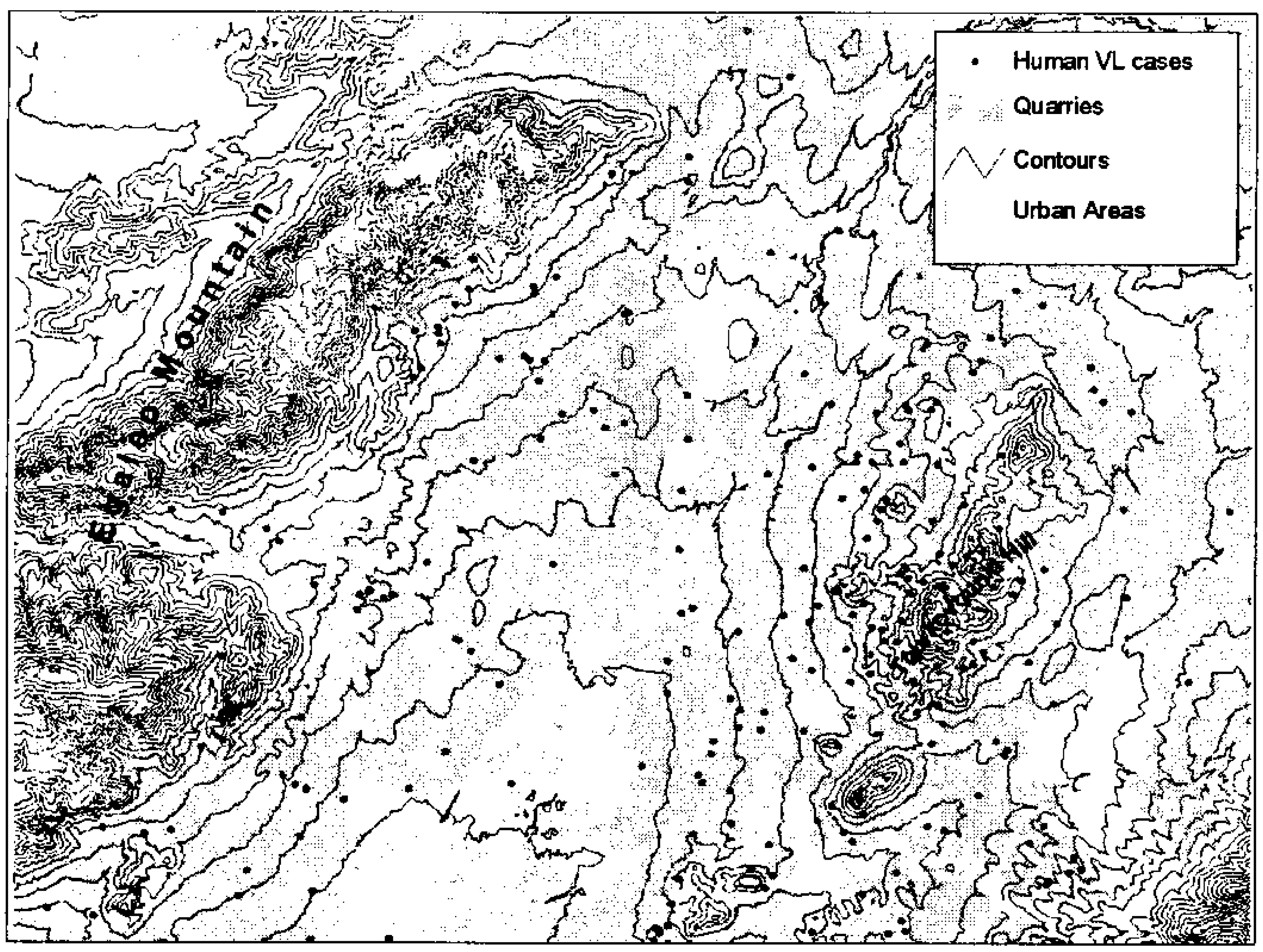

Figure 8: Visualisation of the location of the human VL cases for the period 1961-2000. (A small part of the study area is represented here)

A different visualisation of human VL cases is presented in Figure 9, where the high-risk areas are determined by the frequency of disease appearance per 10000 residents, using as a geographic reference unit the boundaries of the municipalities of the Athens' basin.

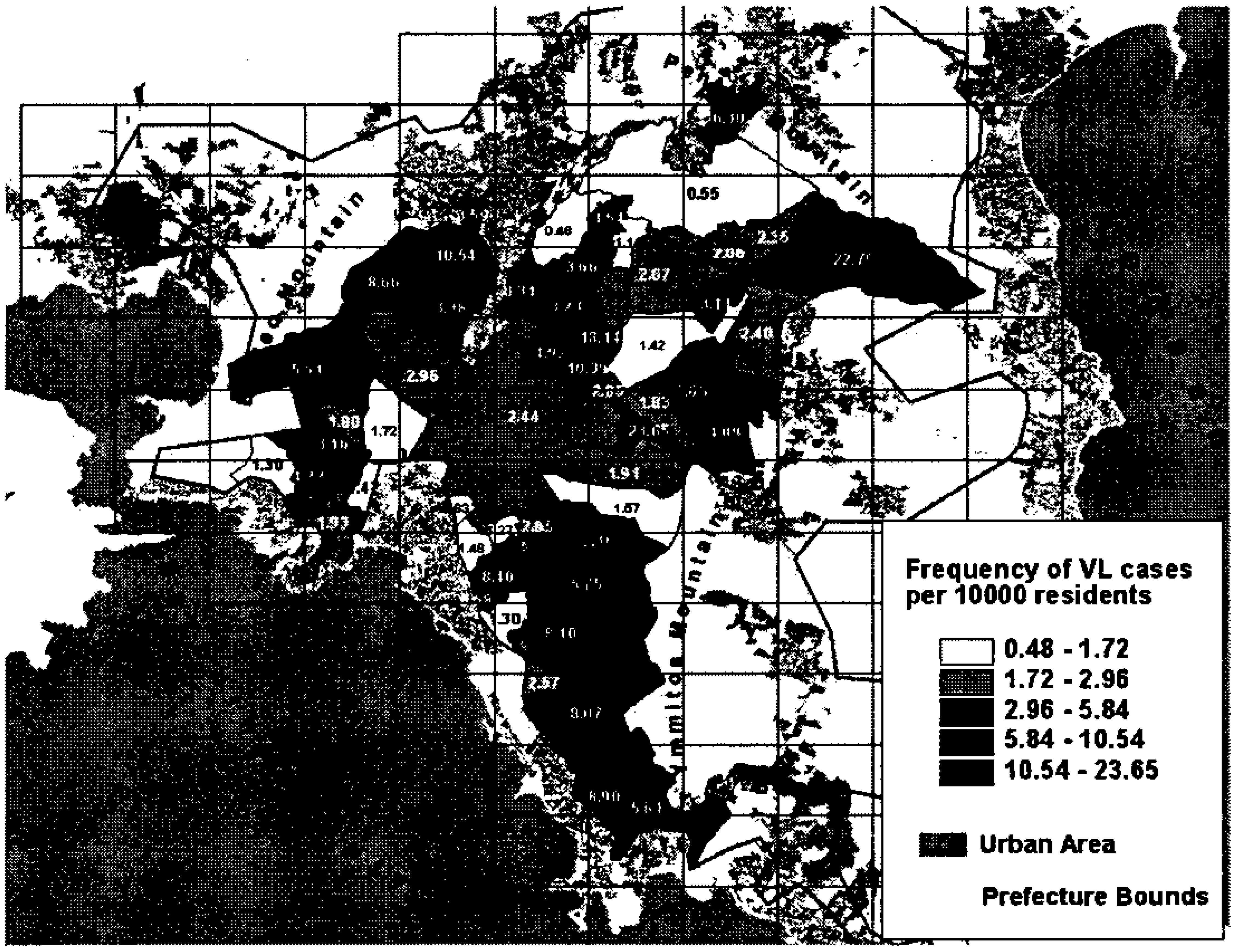

Figure 9: Visualization of human VL cases by the frequency of disease appearance per 10000 residents. (Geographic reference unit is the boundaries of the municipality).

In this map, 1097 cases are included for which the municipality of residence (and not always the exact address) is recorded. Observing this map, it is clear that the high-risk areas are located mostly at the outskirts of the city. The municipalities close to the city center which also present high frequencies of human VL cases are characterized by green urban areas.

Figures 8 and 9 show the spatial patterns which can be associated with environmental factors. Further analysis will be carried out on socioeconomic and meteorological data. In addition, spatiotemporal patterns of urban expansion using remote sensing techniques will be investigated.

4. Concluding Remarks

This paper presents the preliminary results of an on-going research for the distribution and spread of Leishmaniasis in the Greater Athens Region. Human Leishmaniasis cases are related to several environmental factors. The results so far indicate a higher concentration of Leishmaniasis cases in the foothills of mountains and hills, in areas with proximity to quarries and dumps and to high vegetation density areas. Further analysis will include socioeconomic and meteorological data. In addition, the results of the surveys concerning the Phlebotomine sandfly population in the Athens region will be incorporated into the analysis. Human Leishmaniasis cases, environmental factors and sandfly population constitute a series of layers in a geographical data base which provides a visualization of the spread of the disease and the factors related to it. Spatial statistics are considered to be an appropriate method for constructing a model in order to explain the spread of leishmaniasis and provide the means of prediction and surveillance of the disease.

Abbreviations

American Cutaneous Leishmaniasis (ACL)
Digital Elevation Model (DEM)
Geographic Information System (GIS)
Global Positioning Systems (GPS)
Hellenic Military Geographical Service (HMGS)
Hellenic Geodetic Reference System (HGRS)
Integrated Administrative Control System (I.A.C.S)
National Hydrological and Meteorological database (NHMDB)
National Meteorological Service (NMS)
National Statistical Service (NSS)
Phlebotomus Orientalis (P. orientalis)
Remote Sensing (RS)
Technological Educational Institution (T. E. I.)
Visceral Leishmaniasis (VL)
World Health Organization (WHO)
World Geodetic System (WGS)

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Footnotes

1 The Center is WHO Collaborating Center for Research and Training in Mediterranean Zoonoses, University of Crete, Faculty of Medicine, Laboratory of Clinical Bacteriology, Parasitology, Zoonoses and Geographical Medicine, Director: Prof. Y. Tselentis.

2 Technological Educational Institution of Athens, Department of Topography, Sector of Geoinformation and Development studies, 'New technologies in geographic research: a study on the geographical parameters for the distribution and spread of spatial phenomena: An application in Zoonoses', Coordinator: Prof. P. Iliopoulou. This research project is co-funded by 75% from EE and 25% from the Greek Government under the framework of the Education and Initial Vocational Training Program – Archimedes.

3 The Greater Athens Region consists of municipalities.

4 As Rioux et al. reported (1977), the principal determinant of the focus of leishmaniasis in Mediterranean region is the vector. Therefore, the presence and abundance of certain sandfly species in an area could indicate the occurrence of this parasitic infection.

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6 One of the most acceptable and successful models of geographic data representation is the Tomlin model. This model is based on the significance of thematic levels. According to this model, the geographic data compose a hierarchy. At the higher level there is the map, which substantially constitutes a library of thematic levels that are projected to a single system of reference of coordinates. The Tomlin model is important, as it is independent from the approach that is adopted for the representation of reality.

7 According to the official unpublished records, for the period 1961 – 2004 the human cases that it was possible to be exactly localized (that means localized by coordinates X and Y), amount approximately to 37%.