Urban Expansions in the Greater Athens Region and the spread of Zoonoses: The Case of Leishmaniasis.

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Abstract

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[2] which is currently carried out by the Technological Educational Institution of Athens 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. Urban expansions in Athens usually include informal settlements. In this paper data concerning urban expansions will be related to the incidents of leishmaniasis for the period 1985-2004. Urban expansions were derived from satellite imagery processing through GIS, while the geographical distribution of the incidents of leishmaniasis is available for the same time period. The results are combined in a geographical database so that the possible interplay among them can be detected employing methods of spatial analysis.

Keywords

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[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.

Leishmaniasis, Greece, Geographical Information Systems, Informal Settlements, Spatial Analysis, Remote Sensing, Disease risk mapping.

1. Introduction

Since the '90s Geographical Information Systems and methods of Spatial Analysis have been extensively employed in the research concerning the geographical distribution of several diseases [1, 2]. Geographical Epidemiology is a modern discipline in Medical Geography which deals with the analysis of geographical distribution of diseases and aims to the understanding of the mechanisms through which the problems of human health are related to the geographical space. The result of this analysis is the proposal of measures for the control of diseases whose diffusion depends on geographical and environmental factors [3].

Leishmaniases are infectious diseases which are related to environmental factors and present a clear geographical dimension. Those diseases do not affect large populations, however, they are dangerous because at the point they are detected, cure is difficult mainly because they affect people with weak immune system (children, the elderly and patients) and they are often fatal.

The Mediterranean region is one of the areas of the world where a high incidence rate of leishmaniasis is observed. World Health Organization (WHO) has appointed Greece as the Center for the surveillance of zoonoses in the Mediterranean region and the WHO collaborating center is the Laboratory of Clinical Bacteriology, Parasitology, Zoonoses and Geographical Medicine, of the Medical School of the University of Crete.

The disease of Leishmaniasis is caused by Leishmania parasites. Those parasites are a morphologically similar, but biologically diverse, group of organisms which are responsible for a wide spectrum of human disease. Most leishmanial diseases are zoonoses, with a wide variety of natural animal hosts that normally are little affected by the presence of the parasites [4].

The phlebotomine sandflies (Diptera: Family Psychodidae, sub-family Phlebotominae) are the vectors of the various leishmanial diseases of human and other mammals (mainly dogs). Of some 700 phlebotomine species and subspecies, about 70 are considered to be vectors of Leishmania parasites to human. All known or suspected vectors belong either to the genus Phlebotomus (with about 90 species in the Old World: Africa, Asia, Europe, Australasia) [5, 6]. A list of vectors by country is to be found in a WHO Expert Committee report on the leishmaniases [7].

In Greece occur two types of Leishmaniases: Visceral (main) and Cutaneous. Visceral Leishmaniasis known as kala – azar is located almost in the whole country and affects mainly the small children. Phlebotomines are activated when the weather is hot (usually from May to October) and bite dogs and humans during the night (Figure 1).
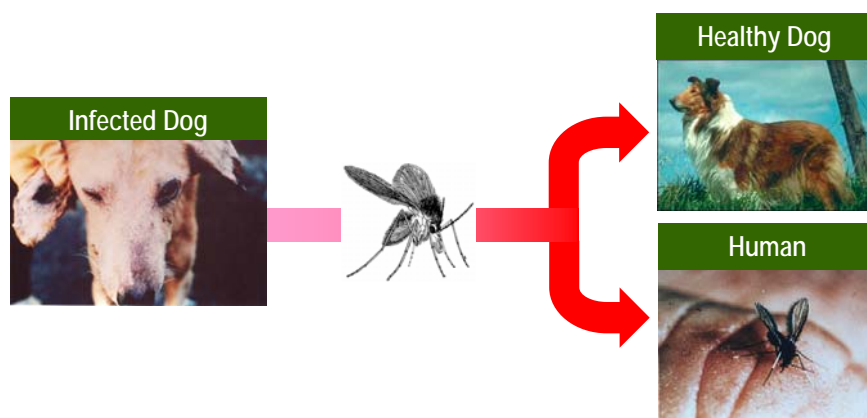
Figure 1. The transmission of parasite to humans and dogs through phlebotomines.

2. Environmental factors affecting the spread of Leishmaniasis

According to Diggle [8], "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. [9] 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:

- ☐ The presence of dogs, cows, Balanites trees and a high density of trees.
- ☐ Host factors (economic status, daily activity, age, gender and ethnic origin)

The results 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. [10] 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 uses 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 Normalized 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. [11]

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 [12].

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. [13]

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. [14]

The Leishmaniases are also shown to be related to urbanization 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. [15]

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. [16]

A study made by Papadopoulos B., Tselentis Y., [17] in 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 expansion, human VL. [18]

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.

M.C. Thomson et al. [19] 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. [20]

Moreover, GIS were used to extract and map regression results for environmental variables in the Gedaref State study [21]. VL incidence in each village was calculated from hospital records. By use of logistic and linear multivariate 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 [22], 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 organize into a GIS, environmental data which accurately represent the factors which have been shown to affect the spread of Leishmaniasis.

3. 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. 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 some 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 [23]. 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. More specifically urban expansions toward the mountains are considered to be areas with higher frequency of the disease. A factor leading to this hypothesis is that urban expansions in some areas of Attica are related to illegal housing and thus to poor social and technical infrastructure. According to the literature poor socioeconomic conditions result to higher incidence rates of the disease and in this way areas of urban expansion might be considered in high risk areas.

The data 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 analyzing point patterns are limited only to 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.

4. 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 analyzing 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. [24].

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 [3]. Especially, GIS, as a powerful and integrated set of tools and methodologies for collection, storing, retrieving, analyzing 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 [1]. 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. [2]

Having all the above in mind, as well as the results of an extensive survey on the sandfly population[4] which was 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.

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[3] The Greater Athens Region consists of 124 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.

[5] Papadopoulos B, Tselentis Y, 1994, "Sandflies in the Greater Athens Region Greece", Parasite, 1, 131-140

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 60'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 urbanization and pollution have created unfavourable conditions for the survival of sandflies.

4.1 The study area

In this paper analysis is carried out for all the municipalities of Attica.

It is a highly build-up area with a large population. During the last years, due to an intense urbanization, most of the suburbs which are near the mountains surrounding the city have been expanded towards the slopes. (Figure 2).
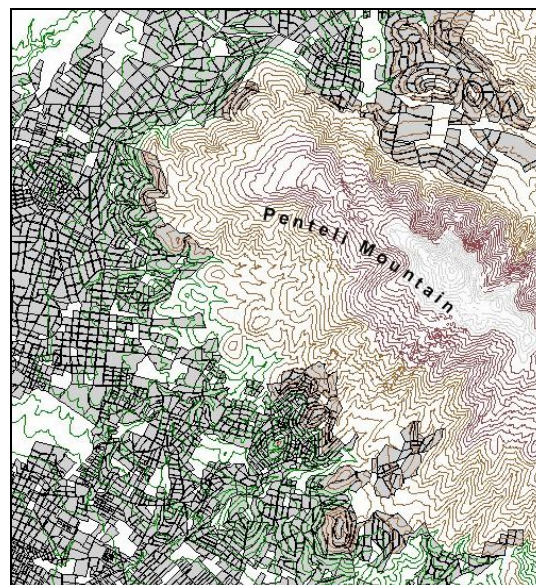
Figure 2: Most of the suburbs of the city of Athens which are near the mountains surrounding the city have been expanded towards the slopes.

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 3a and 3b).
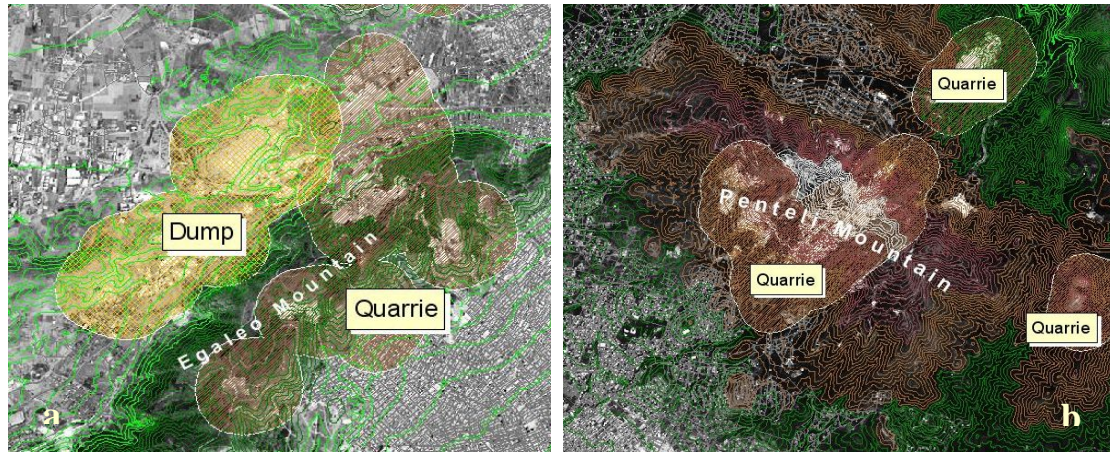
Figure 3: Many quarries and dumps, in several cases are found very close or adjacent to the urban areas of the suburbs of the city of Athens.

4.2 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 GeoInformatics 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 concretization of the geographical database, the platform of ArcGIS 9.0 (ESRI Redlands) was selected. The use of Ms 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 user without expertise in relational databases management.

4.3 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.

4.3.1 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 three 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 4).

- *Digital Elevation Model* of the descriptive area (Grid, resolution 20x20 meters, following the Greek Grid).

Figure 4: Panchromatic geo-referenced satellite image (LANDSAT TM, year 2000) of Attica

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

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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

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:
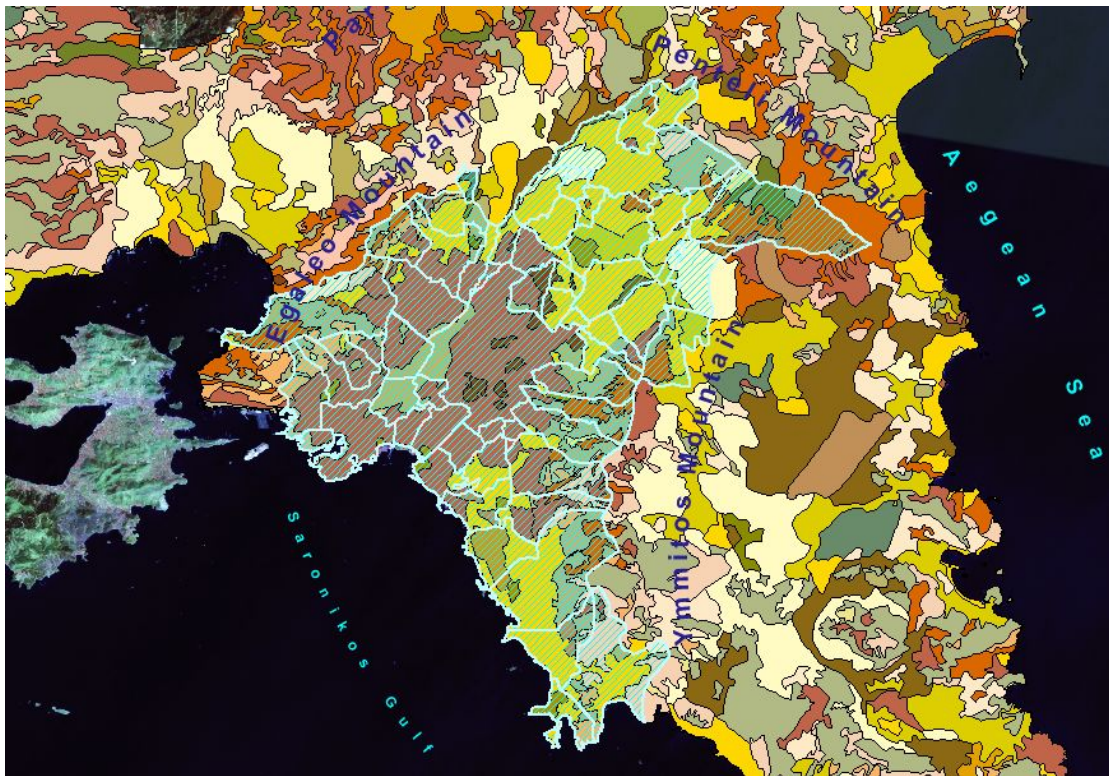
- *Administrative dataset* which has the following thematic layers:
    1. Borders (polygon) that represents the boundaries of Attica derived from the digitization of maps on a scale of 1:50,000 (1990).
    2. OTA50K (polygon) that represents the boundaries of the municipalities derived from the digitization of maps on a scale of 1:50,000 (1996).
    3. 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:
    1. 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).
    2. 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:
    1. 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).
    2. LeishmaniasisCases (point) that represents the locations of the infected from the disease humans (1961-2004)[7].
- *Hydrology dataset* which has the following thematic layers:
    1. Aqueducts (line) that represents the aqueducts derived from the NHMDB (1996).
    2. Rivers (line) that represents the rivers as they derived from a digital elevation model (DEM) based on hypsometrical information from the NHMDB (1996).
    3. Wells (point) that represents the drillings derived from the NHMDB (1996).
- *Land cover dataset* which has the following thematic layers:
    1. Corine (polygon) that represents the land cover on a scale of 1:100,000 derived from E.U. project CORINE LandCover (1994). (Figure 5)
    2. 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).
    3. 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).
- *PointsOfInterest dataset* which has the following thematic layers:
    1. Landmarks (point) that represents the places of important locations of the study area (1990 – 2004) derived from the GeoInformatics Laboratory.
- *TillingSchemes dataset* which has the following thematic layers:
    1. 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 GeoInformatics Laboratory (1992).

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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%.

2.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 GeoInformatics Laboratory (1992).

Figure 5: 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).

- *Topography dataset* which has the following thematic layers:
    1.Contours (line) that represents the contour lines derived from HMGS's maps on a scale of 1:5,000, updated from the GeoInformatics Laboratory (1990-1998).
- *Transportation dataset* which has the following thematic layers:
    1.RailRoadNetworkNHMDB (line) that represents the railway network in Attica prefecture on a scale of 1:50,000, updated from the GeoInformatics Laboratory (1998-2002).
    2.StreetNetwork (line) that represents the street network in Attica prefecture on a scale of 1:5,000, updated from the GeoInformatics Laboratory (1998-...).

4.3.2 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.

4.4 Data analyzing and mapping

As it is 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 the figure 6 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.
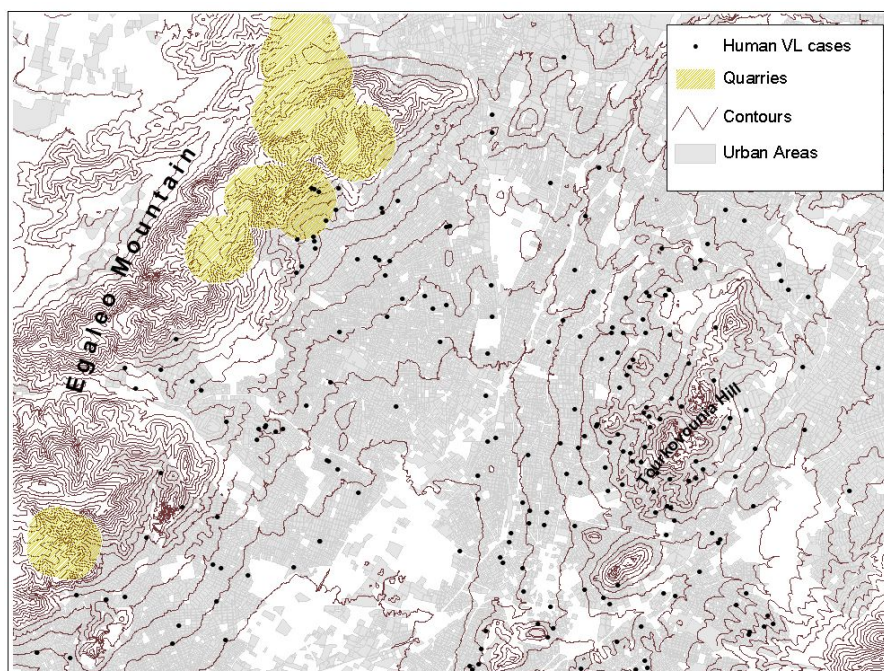
Figure 6: Visualization of the location of the human VL cases for the period 1961-2000. (A small part of the study area is represented here)

A different visualization of human VL cases is presented in figure 7, 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.
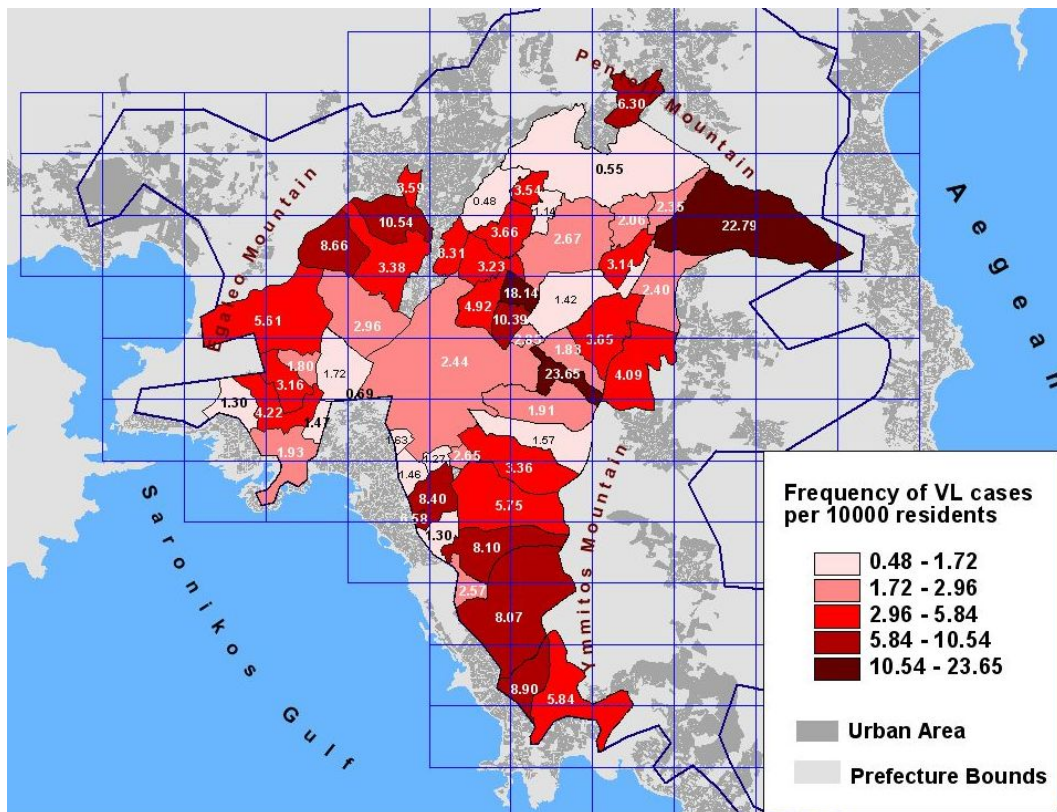
Figure 7: Visualization of human VL cases by the frequency of disease appearance per 10000 residents for the whole period of study (1961-2004).
(Geographic reference unit is the boundaries of the municipality).

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 6 and 7 show the spatial patterns which can be associated with environmental factors.

The mapping of urban expansions for the prefecture of Attica was performed for the time periods 1989-1995 and 1995-2004. These periods were predetermined by the availability of epidemiological data and satellite images.

The method that was used for the mapping is that of qualitative photo interpretation. Before the method of qualitative photo interpretation is carried out, the following steps should be taken: The collection of digital data (images), the radiometric - geometric correction of images, the choice of basic categories of land uses/ covers that will be interpreted qualitatively, the choice of classification system of uses /covers of land and the choice of image channels.

The choice of digital satellite images that were collected was made on the basis of the spatial accuracy, the radiometric accuracy and the spectral sampling of the image.

After data collection satellite images were georeferenced to the Greek Grid. Radiometric corrections were not necessary, because the quality of pictures was considered well enough for the particular application. Finally, the following categories of land uses/covers, were selected to be interpreted by the satellite images:

 □ continuous urban fabric,

 □ discontinuous urban fabric,

 □ construction sites and

 □ green urban areas.

The photo interpretation of the above categories was performed in the scale 1:18.000. In addition the geo-classification system of Corine LandCover was used to test the results.

Three different satellite images were employed in order to delineate the areas of urban expansions in Attica referring to the years 1989, 1995 and 2004.

The results of the above analysis concerning the urban expansion areas in Attica are presented in a series of maps (figure 8) where the urban expansions are shown in yellow. As expected, urban area in Athens presents a continuous growth for the time period 1989-2004.

For the period 1989-1995 the largest areas of urban expansions are observed in certain municipalities close to Parnis mountain (Acharnai, A. Liossia), in Mesogaia region (Koropi, Keratea, Kalyvia) as well as in Aspropyrgos, while for the period 1996-2004 urban expansions are more obvious in the same regions (Acharnai, Koripi, Aspropirgos, Markopoulo) as well as in Marathon. All the above municipalities are known for the presence of illegal housing. In general from figure 8 it is obvious that areas of urban expansion present a remarkable spatial concentration along the eastern coast of Attica.
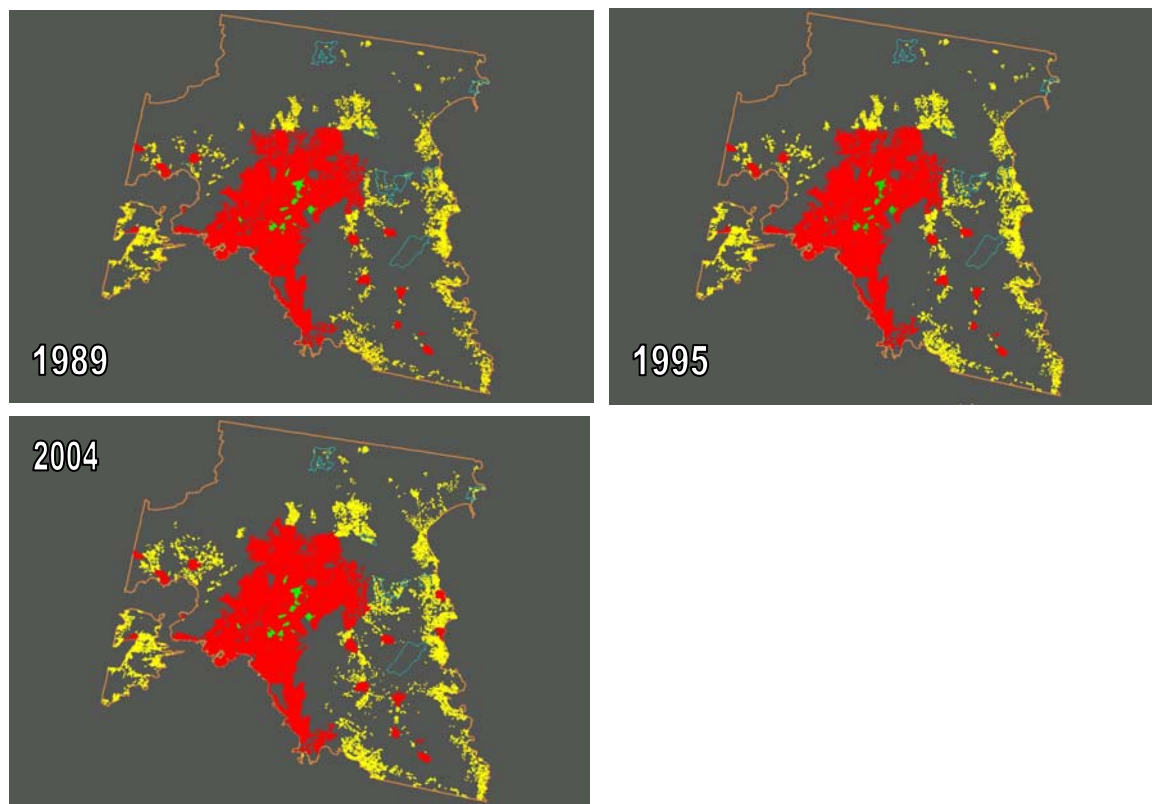

Figure 8: Urban expansion trough the period 1989 - 2004

The final step of this analysis was to examine the hypothesis that the incidence of the disease is associated with urban expansions. For that purpose the data concerning cases of leishmaniasis were divided in the same time periods for which urban expansions in Greater Athens were extracted from the satellite images, i.e. 1989-95 and 1996-2004. The incidence rates for those time periods were mapped in conjunction to urban expansions. The results are shown in figures 9 and 10.
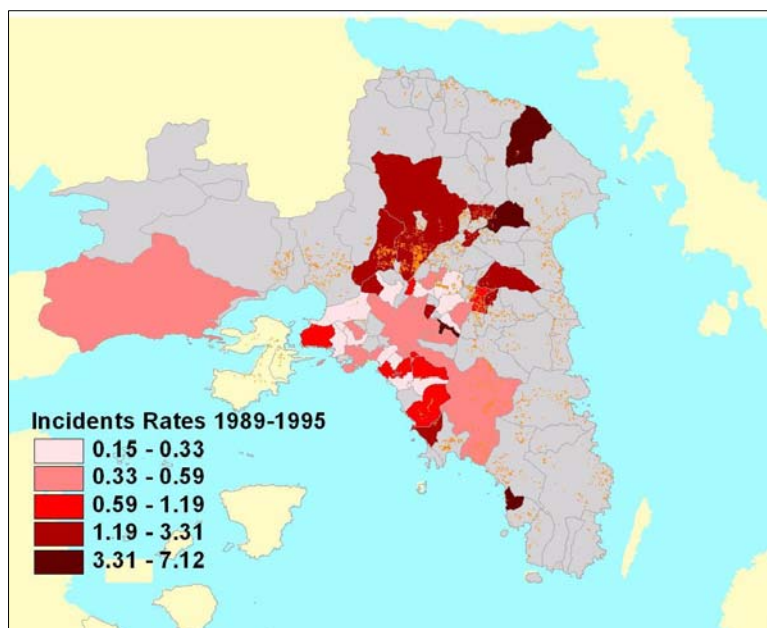
Figure 9
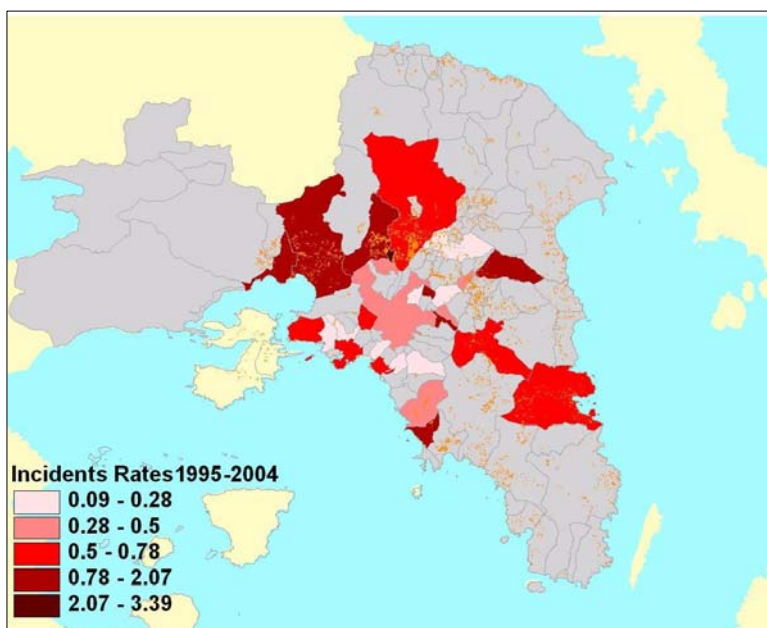
Figure 10

For the period 1989-1995 the highest incidence rates of the disease are observed in certain municipalities (Varnava, Saronida, Stamata, Petroupolis) close either to the hills surrounding the Greater Athens Region or to the coast.

For the period 1996-04 the highest incidence rates of the disease are observed in municipalities close to hills and mountains mostly in the western suburbs of Athens (Zefiri, Liossia, Petroupoli, Penteli)

The association between urban expansion and incidence rates of leishmaniasis was tested employing several statistical techniques. At first descriptive statistics techniques were used, cross tabulation and the associated Chi-square statistic. Two different variables were associated in this manner with the area of urban expansions for the above time periods: the number of cases of leishmaniasis and the incidence rate (cases per 10000 inhabitants). The results show that urban expansions and cases or incidents of leishmaniasis are associated for the period 1989-1995. For this period the results are statistically

significant. For the period 1996-2004 the results are rather ambiguous and it is not possible to establish a definite association in terms of the Chi-square statistic.

In addition, the Pearson correlation coefficient was calculated for the same combinations of variables, which yielded no significant linear correlation. Furthermore, spatial autocorrelation was tested with the calculation of Moran's I coefficient [25]. For the period 1989-95 Moran's I shows statistically significant autocorrelation for the variable which describes the number of the cases. This is not however the case for the second period for which the results are not conclusive.

5. Concluding Remarks

This paper presents results from an on-going research concerning the distribution and spread of leishmaniasis in the Greater Athens Region. Human leishmaniasis cases are related to several environmental factors, such as altitude, proximity to quarries and dumps and dense vegetation. In addition urban expansions is another factor contributing to the emergence of leishmaniasis which appears in the bibliography. Human Leishmaniasis cases, environmental factors, sandfly population as well as urban expansions 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. In this paper urban expansions were examined as one of the factors which contribute to leishmaniasis. This factor however may be considered to be associated to other factors as well, particularly geomorphology and social conditions, illegal housing being one of them. Data on illegal housing were not available in this work and mapping of urban expansions was considered as an indication of the area and location of illegal housing especially in areas outside the city center and closer to the outskirts of the city and the coast.

The results of the satellite image analysis were combined with empirical information on illegal housing. It appears that in the period 1989-94 the geographical pattern of the disease is associated with urban expansion and probably with illegal housing in a statistically significant way. The highest incidence rates of the disease are observed in certain municipalities close either to the hills surrounding the Greater Athens Region or to the coast. In addition the largest area of urban expansions is observed in certain municipalities near Parnis. All the above municipalities are known for the presence of illegal housing. Illegal housing might contribute to the spread of the disease due to the possible lack of infrastructure and poor standards of living conditions. For the period 1996-04 the results of the analysis are not statistically significant; however, the highest incidence rates of the disease are observed again in municipalities near Parnis and Penteli, while urban expansions are more obvious in the outskirts of the city. The fact that the correlation of incidence rates and urban expansions is not statistically significant may be attributed to the fact that urban expansions in this period refer to legal housing in areas incorporated to the city plan. In general, the complexity of the factors which influence the geographical distribution of the disease appears to hamper the exploration of individual factors.

6. Citations

[1] Meade M, Earickson J. R. Medical Geography, second edition. 2000; The Guilford Press, London.

[2] Mbarki L, Ben Salah A, Chlif S, Chahed M.K, Balma A, Chemam N, Garraoui A, Ben-Ismail R. GIS for Health and the Environment. International Workshop. Proceedings.1994; Colombo, Sri Lanka

[3] Tsatsaris A. A study of the geographical parameters of influence of the mechanisms for the spatial diffusion of diseases. National and international developments and future prospects. 1st National Congress of the Hellenic Association for Geographical Information (Hellas GI). http://www.hellasgi.gr/1oSynedrio/4tsatsar/4tsatsar.pdf and Proceedings (CD). November 1999; Athens, Greece

[4] Lane, R.P. Phlebotomine sandflies. In: Manson's tropical diseases, 19th edition, Eds. P.E.C. Manson-Bahr & D.R. Bell, London, Bailliere Tindall,1987, pp.1395-1404.

[5] Lewis, D.J. The phlebotomine sandflies (Diptera: Psychodidae) of the Oriental Region. Bulletin of the British Museum (Natural History), Entomology Series, 37: 217-343 (1978).

[6] Lewis, D.J. & Ward, R.D. Transmission and vectors. In: The leishmaniases in biology and medicine [vols.1 & 2]. Eds. W. Peters & R. Killick-Kendrick, London & New York, Academic Press,1987, pp. 235-262.

[7] WHO Technical Report Series, No. 701,1984 (The leishmaniases, report of a WHO Expert Committee), 140 pp.

[8] Diggle, P. D, Point process modelling in environmental epidemiology. Statistics for the environment. Vic, B.; Turkman K. F. (ed.). Wiley, London, UK. 1993.

[9] Bucheton B, Kheir M. M, Hassan El-Safi S, Hammad A, Mergani A, Mary C, Abel L, Dessein A. The interplay between environmental and host factors during an outbreak of visceral leishmaniasis in eastern Sudan. Microbes and Infection 2002; 4: 1449–57.

[10] Patz J. A, Graczyk T, Thaddeus K, Gellera N, Vittor A. Y. Effects of environmental change on emerging parasitic diseases. International Journal for Parasitology 2000; 30: 1395-1405

[11] Thomson M. C, Connor S. J. Environmental Information Systems for the Control of Arthropod Vector of Disease. Medical and Veterinary Entomology 2000; 14: 227-244.

[12] Karam V. Singh. Studies on the role of climatological factors in the distribution of phlebotomine sand flies (Diptera: Psycholidae) in semi-arid areas of Rajastan, India Journal of Arid Environments 1999; 42, 1: 43-48.

[13] Thomson M. C, Connor S.J, op. cit., page 227

[14] Elnaiem D. E, Schorscher J, Bendall A, Obsomer V, Osman M. E, Mekkawi A. M, Connor S. J, Ashford R. W, Thomson MC. Risk mapping of visceral leishmaniasis: the role of local variation in rainfall and altitude on the presence and incidence of kala-azar in eastern Sudan. The American Journal of Tropical Medicine And Hygiene2003; 68, 1:10-17.

[15] Machado-Coelho G. L, Renato A, Mayrink W, Caiaffa W. T. American cutaneous leishmaniasis in Southeast Brazil : space-time clustering. International Journal of Epidemiology 1999; 28, 5: 982-989.

[16] Neouimine. N.I. Leishmaniasis in the Eastern Mediterranean Region. WHO, TDR Publications, TDR-IDRI Meeting Report. 1996; 2, 1: 94-101

[17] Papadopoulos B, Tselentis Y. Sanflies in the Greater Athens Region Greece. Parasite 1994; 1: 131-140

[18] Chaniotis B., Gozalo Garcia G and Tselentis Y. Leishmaniasis in Greater Athens, Greece. Entomological studies, Annals of Tropical Medicine and Parasitology. 1994; 88: 659-663.

[19] Thomson M. C, Einaiem D. A, Ashford R. W, Connor S. J. Towards a kala azar risk map for Sudan: mapping the potential distribution of Phlebotomus orientalis using digital data of environmental variables. Tropical Medicine and International Health. 1999 ; 4, 2: 105-113.

[20] Thomson M. C, Connor S.J, op. cit., page 227.

[21] Gebre-Michael T, Malone J. B, Balkewa M, Alia A, Berhe N, Hailu A, Herzi A. A. Mapping the potential distribution of Phlebotomus martini and P. orientalis (Diptera: Psychodidae), vectors of kala-azar in East Africa by use of geographic information systems. Acta Tropica. 2004; 90: 73–86.

[22] Machado-Coelho et al., op. cit., page 984.

[23] A. Tsatsaris, P. Iliopoulou, A. Panagiotopoulou, Y. Tselentis, 2005 "A Geographical Database for the Control of Leishmaniasis: The Case of Greater Athens, Greece". The Tenth International Symposium on Health Information Management Research (ISHIMR)

[24] Thomson M. C, Connor S.J, op. cit., page 227

[25] Fotheringham A.S., Brundson C. , Charlton M. Quantitative Geography, 2002, SAGE Publications, London.