DOI: 10.1515/cerce-2017-0018
Available online: www.uaiasi.ro/CERCET_AGROMOLD/
Print ISSN 0379-5837; Electronic ISSN 2067-1865

Original Article

Cercetări Agronomice în Moldova
Vol. L , No. 2 (170) / 2017: 91-100

GEOGRAPHIC INFORMATION SYSTEM (GIS) AS A TOOL IN THE EPIDEMIOLOGICAL ASSESSMENT OF WETWOOD DISEASE ON ELM TREES IN TABRIZ CITY, IRAN

M. ALIZADEH[1]*, M. MOHARRAMI[2], A.A. RASOULI[2]

*E-mail: mehrdad.alizadeh14@yahoo.com

Received: Mar. 13, 2017. Revised: May 22, 2017. Accepted: May 27, 2017. Published online: June 30, 2017

ABSTRACT. Plants disease epidemiology provides us with some information about the spread of diseases in different regions with various climates and helps us conduct suitable managing operations and predictions about the spread of disease to other areas. Geographic Information System (GIS) has been widely used as an important tool in epidemiological studies. Wetwood disease is one of the most important bacterial diseases on elm trees found in the Northwest of Iran. The disease has spread in different regions of Tabriz (located in the Northwest of Iran), which has become terribly epidemic. Geographic Information System as an appropriate tool in epidemiological examination of plant disease is useful in various ways. In this study, the epidemiology of bacterial wetwood disease on elm trees in Tabriz was investigated using GIS databases. The results indicate that the disease has become epidemic in different areas of Tabriz. According to the results, although the disease was not found in some regions, its severity was very high in some other areas. Based on the distribution map, the wetwood disease most highly exists in the central regions and some parts of the northern regions of the city, but eastern regions are least affected.

Keywords: plant disease; epidemiological studies; bacterial wetwood; Iran.

INTRODUCTION

Elms (*Ulmus* spp. L.) are deciduous and semi-deciduous trees in the plant family of Ulmaceae. Elm trees flourish and spread over most of the Northern hemisphere, inhabiting the temperate and tropical-montane regions of South and central America and North Africa, Indian Eastern islands and parts of the Southern hemisphere. Elm trees are the most common trees used in natural landscapes across the world (Santini *et al*., 2002) since they are usually tall

[1] University of Tabriz, Department of Plant Protection, Iran
[2] University of Tabriz, Department of Remote Sensing & GIS, Iran

and have beautifully shaped branches and leaves which make them attractive. In addition, elm trees are salt resistant and grow fast in any kind of soil, have valuable wood, and tolerate moving and physical pressures and soil condensation. These features have made them more and more popular across the Europe and North America and other parts of the world (Santini *et al.*, 2002). On the other hand, elm trees play a key role in improving biodiversity by providing a good habitat for their related species and obviating them reduces biodiversity (Yau, 1994). There is no accurate estimate about the number of elm trees in the world or even in the countries; however, it has been estimated that there are 136 million elms trees with more than 10 cm in diameter around the world, of which 95% are found in Europe, Asia and North America (Stipes and Campana, 1981). Iran is also among the countries in which specific species of elm trees have spread; however, no comprehensive information or distribution map are available (Iraqi *et al.*, 2008).

More than 5000 bacterial species have been identified, of which 100 species are known as plant pathogens. Damage caused by bacterial diseases can have considerable economic importance (Sobiczewski, 2008). Wetwood is one of the most important diseases on elm trees, which has become epidemic across the globe. The disease occurs in many mature trees, including elms, ash, acacia, spruce, oak, acer, willow, mulberry and gymnosperms (Mohan *et al.,* 1990). The disease was first reported in the United State in 1945 (Carter, 1945). The symptoms are usually seen in different parts of trees such as trunk, branches, roots and leaves. The most obvious symptom is the appearance of either light or dark long vertical streaks on the trunks resulting from slimy liquid oozing out of cracks or wounds and running down the bark, which is called 'slime flux' (Murdoch and Campana, 1983). If an affected tree is cut down, the heartwood is darker in color than surrounding wood, thus the name is 'wetwood' (Murdoch and Campana, 1983). The disease is responsible for a big issue in forest industry, as the disease causes dieback and cracks or wounds on the timbers, affecting the quality of their logs (Ward, 1972).

Plant disease epidemiology is the study of disease in plant population. As a sub branch of plant pathology, it is concerned with the factors that cause plant epidemics and their interaction with environment over time and in different places (Campbell and Madden, 1990). Modern techniques in epidemiologic studies have been widely expanded by investigating the disease outbreaks in 19^{th} century. Epidemiologic methods can estimate the risk of disease with high accuracy. In addition, well designed and properly performed epidemiologic studies can predict disease outbreak and thus prevent unnecessary costs and inappropriate managing operations (Blumenthal *et al.*, 2001). In 1977, it was claimed that infection of trees with wetwood disease is caused by pruning and also the wounds caused by lawn mowers (Hilis, 1977).

Epidemiologists use different maps while analysing the relationships between location, environment and disease. In fact, GIS is widely used in this filed due to its spatial analysis and display of capabilities. In other words, GIS methods and epidemiologic studies have been integrated well to identify and estimate danger of diseases (Clarke *et al*., 1996). GIS is a computer system for evaluating, manipulating, categorizing, and displaying data in two- or three-dimensional maps using geographical data (Star and Estes, 1990). Information management, will be a key for improving agricultural practices in future decades. Organizing agricultural information in spatial databases seems logical, given that agricultural systems are inherently spatial. Biological and physical aspects of agricultural systems create spatial heterogeneity, which leads to patchiness distributing plant pathogens and diseases (Campbell and Madden, 1990). GIS shows disease activity and distribution and helps us to take an appropriate action when disease is encountered. Plant disease management would improve by using epidemiologic data and GIS methods (Jebara, 2007). In addition, GIS has been used to analyse in the spatial and temporal characterization of plant diseases, developing plant disease distribution maps and detecting pathogens genotypes for a better management of plant diseases (Nutter *et al.,* 1995; Orum *et al.,* 1997).

The current study was performed to investigate wetwood distribution in different regions of Tabriz using epidemiologic data and GIS analysis methods.

MATERIALS AND METHODS

Counting the trees and counting range

Since elm trees were mostly found on the main streets in the city of Tabriz, we randomly selected sites for counting the total and infected number of trees over the main streets located in different parts of the city. The counting process was conducted over an area of 1000 m^2. In each area first the total number of trees and then the total number of infected trees were counted. To obtain the rate of infection in each area, the number of infected trees was divided by the total number of trees in that area and 10 multiplied by 100. Once the rate of infection was calculated for each area, the total rate of infection in the city of Tabriz was calculated by dividing the total number of infected elm trees in all areas by the total number of elm trees in all areas and multiplying the result by 100.

Given that the infection reveals its symptoms in cooler temperatures, the process of counting total and infected trees in each area was carried out at temperatures below ten degrees over a span of several weeks.

Disease diagnosis

The first step to evaluate the percentage of infected trees was to find regions with elm trees. The first symptom of the disease is the slimy, sometimes foul smelling liquid, which bubbles out of the tree and runs down the trunk. These liquids ooze out of pruned sites (*Fig. 1-a*), cracks (*Fig. 1-b*) or wounds (*Fig. 1-c*) and run down the trunk. Given that, the infected trees were identified around the city, coded and numbered and then disease percentage was calculated.

1-a **1-b** **1-c**

Figure 1 - Symptom of wetwood disease on elm trees

Study area

The study was performed in Tabriz, the most populated city in Iranian Azerbaijan, and the present capital of East Azerbaijan Province. Tabriz's coordinates ranges from 46°10′ to 46°24′E and from 38°01′ to 38°08′ N and its average elevation is 1,320 meters above sea level. Elm trees are widely planted in Tabriz city on streets and in park areas so that most of the landscapes in Tabriz city are dominated by elm trees.

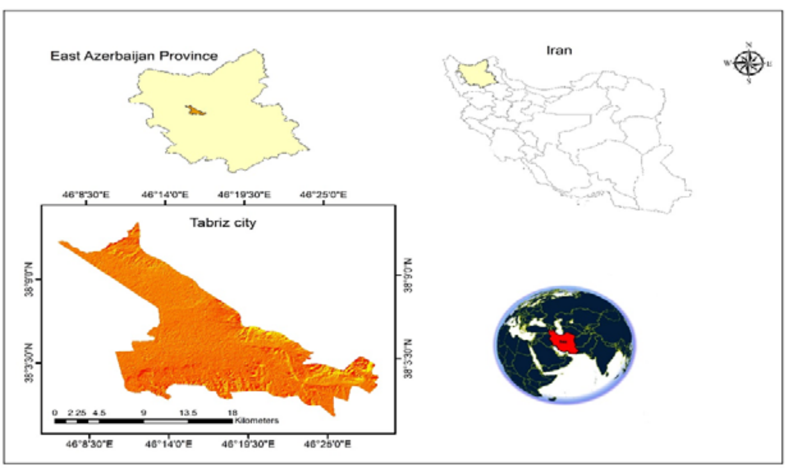

Figure 2 - Map of the studied area

GPS data

Manual Global Positioning System (GPS) device, model of Garmin, was used to collect the data. The GPS network consists of 24 satellites (located 19,300 km above the earth's surface circling the globe twice a day), which transmit spatial and temporal navigation data (Long wave radio signals) 24 hours a day free of charge. For this purpose, 36 locations were collected in which disease percentages were calculated. ArcGIS version 10.3 was used to analyze the data and develop the maps. In the input layer of descriptive information table, the disease percentage of each location was imported for further interpolation and map developing.

Importing the data to GIS

By examining the fields and collecting data using GPS, coordinates of each location was imported into ArcGIS and the vector layer was created as shapefile format. This format can spatially describe vector features: points (as X and Y), lines (as sets of points), and polygons (as sets of lines). Descriptive information represents qualitative and quantitative attributes of geographical coordinates. Descriptive information table is an efficient and flexible table for searching, recovering and manipulating as well as preparing the reports (Chang, 2016). In descriptive information table, disease percentage values and locations and related information were imported into the intended layer.

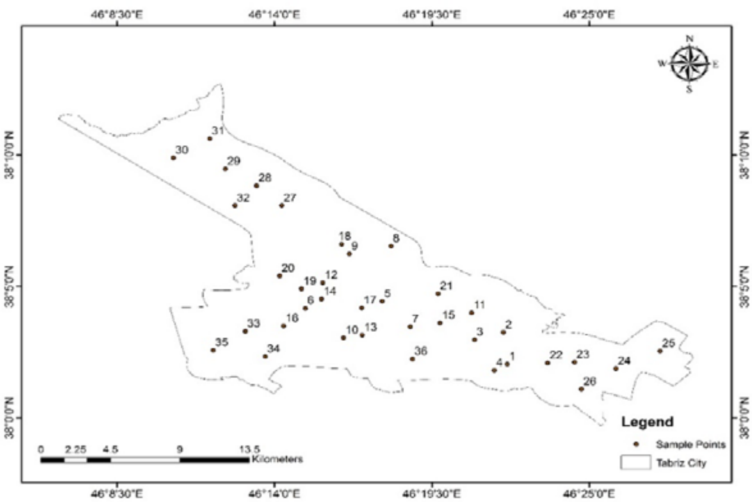

Figure 3 - Sampling position

Data interpolation and developing disease distribution maps

Interpolation is a method of constructing new data points within the range of a discrete set of known data points. The interpolation output can be used as a map or layer in GIS analysis (Ghahrooditali and Babaefini, 2014). Kriging model was used to interpolate the data. This model is one of the most important and expanded interpolation models.

RESULTS

The results are shown as mean values with standard errors. The disease percentage data in 36 regions and total Tabriz reported in *Tables 1 and 2*, respectively, and showed that the wetwood disease had an outbreak in 29 regions (more than 80% of total area of Tabriz). Despite the decline and development, symptoms are likely to progress on healthy trees in the future years.

Table 1- Disease percentage in different regions of Tabriz

Disease percentage (%)	Infected trees	Total trees	Region	Disease percentage (%)	Infected trees	Total trees	Region
83.64	92	110	19	18.91	7	37	1
58.97	23	39	20	84.61	22	26	2
88.71	93	109	21	29.09	32	110	3
0	0	0	22	37.25	38	102	4
0	0	0	23	74.41	64	86	5
0	0	0	24	81.20	108	133	6
0	0	0	25	65.75	48	73	7
0	0	114	26	75	6	8	8
36.55	34	93	27	0	0	0	9
38.09	16	42	28	62.16	115	185	10
40.54	15	37	29	61.11	66	108	11
39.28	22	56	30	69.38	34	49	12
37.50	15	40	31	77.04	47	61	13
41.30	19	46	32	79.62	43	54	14
54.65	47	86	33	69.44	75	108	15
63	63	100	34	54	27	50	16
56	42	75	35	77.01	67	87	17
62	93	150	36	0	0	0	18

Table 2 - Total disease percentage in Tabriz

Total disease percentage in Tabriz city (%)	Total number of infected trees in 36 regions	Total number of trees in 36 regions
57.83	1373	2374

Among the potential sites of wetwood disease that concern our study, the prevalence of disease was found to be high and very high in 2, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 33, 34, 35 and 36 regions; very low and low in 1, 3, 4, 27, 28, 29, 30, 31 and 32 regions, and without disease in 9, 18, 22, 23, 24, 25 and 26 regions (*Table 1*). In fact, the central regions of Tabriz have high percentage of disease. Based on our results, the disease had an outbreak in the most important regions of Tabriz city, but several regions were not affected (*Fig. 4*). The Western and Eastern regions showed the minimum disease incidence, because these regions, generally, haven't elm trees. Based on these results (*Table 2*), the data indicate that except for district 26, where the trees had newly been planted, in all other areas, wherever elm trees were found, wetwood disease was also to be found. The number of infected and uninfected trees varied in different areas and no correlation was found between the number of trees and the rate of infection.

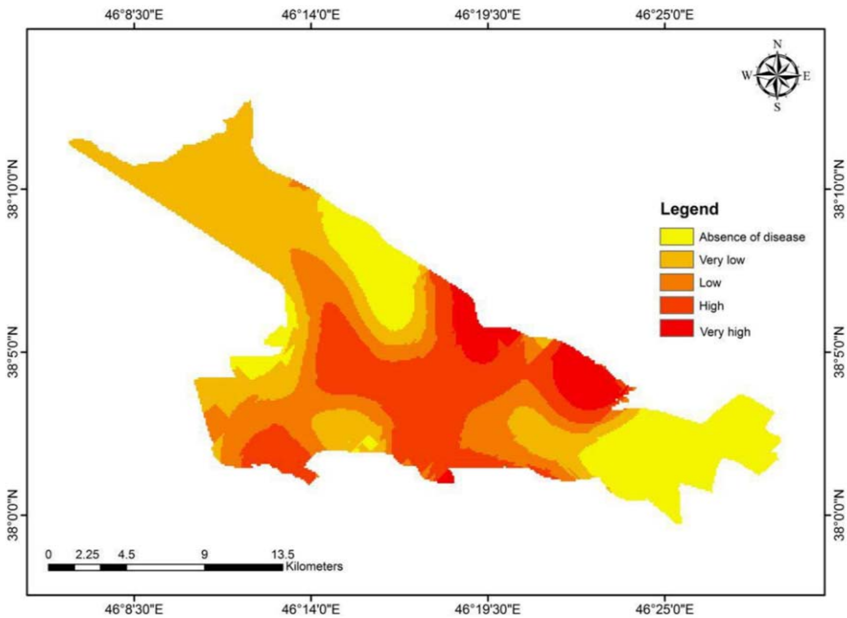

Figure 4 – Disease distribution map across Tabriz city

DISCUSSION

In the past years, GIS was used in plant pathology for evaluating epidemiological maps in the case of plant pathogens. For example, distribution and epidemiology of *Aspergillus flavus* and its several diseases were investigated, such as tomato virus, Late blight of tomatoes and potatoes, Cotton leaf curl disease and Cotton leaf crumple disease (Nelson *et al*., 1999). GIS was used to analyse genetic structure of *Phytophthora infestans* in Mexico (Jaime-Garcia *et al.,* 2001). In 2002, Thomas and co-workers used GIS techniques for developing risk maps of 12 diseases to take an appropriate action (Thomas *et al.,* 2002). In a study, GIS methods were used to study spatial relationships between plant tissue, crop rotation and *Aspergillus flavus* population in the soil (Jaime-Garcia and Cotty, 2006). Moreover, GIS was used to study the effect of planting density on disease distribution in Malaysia (Azahar *et al.*, 2011; Taliei *et al.*, 2013).

The main reasons for disease dispersion may be due to the following factors: high population of trees with overlapping branches, high relative humidity in these regions, pruning and creating wounds on the trees (Agrios, 2005). In 1977, it was believed that pruning and wounding the trees by lawn mowers are the main reasons for wetwood disease (Hilis, 1977). Based on our observation, the maximum oozing was found on pruned trees. Therefore, it can be concluded that pruning with infected tools can increase the risk of the disease dispersion. Due to the outbreak of wetwood disease in most parts of Tabriz, preventive measures should be taken (such as preventing tree injuries, improper trimming, non-sterilized trimming equipment and supplementing the trees with proper nutrition) in order to impede the progress of the disease and to prevent it from infecting the uninfected areas.

CONCLUSION

GIS as a novel technology has created an important development in environmental studies. Input data is the most important part in GIS, so that more accurate data results in more accurate outcomes. Epidemiologic studies are not an exception. GIS technology can be useful in evaluating epidemiologic studies of many diseases in different regions; however, the required costs for each disease should be considered. In order to increase the accuracy in GIS analyses, environmental factors and other effective parameters in distribution of disease should also be taken into account.

Acknowledgments. We would like to acknowledge the University of Tabriz for its long-standing work. Furthermore, we are thankful to the nameless reviewers whose positive feedback significantly stepped forward the excellence of the manuscript.

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