

Inverse Distance Weighted (IDW) Distribution Mapping of *Phlebotomus papatasi*, *Phlebotomus tobbi*, and *Phlebotomus sergenti* in Çukurova Region, Turkey

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Abstract: *Phlebotomus (P.) papatasi*, *P. (P.) tobbi*, and *P. (P.) sergenti* species occur as the main vectors for Cutaneous Leishmaniasis (CL) in Çukurova Region (Adana, Mersin, Osmaniye), Turkey. The Inverse Distance Weighted (IDW) method was used to demonstrate the distribution modeling of *P. papatasi*, *P. tobbi*, and *P. sergenti* collected from Çukurova Region. According to the Inverse Distance Weighted (IDW) method, the center of the dispersal of all three sand fly species was demonstrated as İmamoglu where the CL disease is common.

Keywords: *inverse distance weighted*, *IDW*, *Phlebotomus papatasi*, *Phlebotomus tobbi*, *Phlebotomus sergenti*, *Çukurova*, *Turkey*

Çukurova Bölgesindeki *Phlebotomus papatasi*, *Phlebotomus tobbi* ve *Phlebotomus sergenti*, Türlerinin Ters Uzaklık Ağırlıklı İnterpolasyon Yöntemi ile (IDW) Dağılımlarının Haritalanması

Öz: *Phlebotomus (P.) papatasi*, *P. (P.) tobbi* ve *P. (P.) sergenti* türleri kütanöz leşmanyöz'ün (CL) Türkiye'nin Çukurova Bölgesi'nde ana vektörleridir. Çukurova Bölgesi'nden (Adana, Mersin, Osmaniye) toplanan *P. papatasi*, *P. tobbi* ve *P. sergenti*'nin dağılım modellemesi için ters uzaklık ağırlıklı interpolasyon (IDW) yöntemi kullanılmıştır. IDW yöntemi sonuçlarına göre CL hastalığının yaygın olduğu İmamoglu üç kum sineği türü için dağılım merkezi olarak görülmektedir.

Anahtar kelimeler: ters uzaklık ağırlıklı interpolasyon yöntemi, *IDW*, *Phlebotomus papatasi*, *Phlebotomus tobbi*, *Phlebotomus sergenti*, *Çukurova*, *Türkiye*

1. Introduction

Leishmaniasis are vector-borne diseases caused by flagellated protozoans of the genus *Leishmania*. This disease is endemic in large areas of the tropics, subtropics, and Mediterranean and is found in 98 countries. There are over 350 million people at risk and 12 million cases with an estimated worldwide annual incidence of 0.7-1.2 million cases of cutaneous leishmaniasis (CL) and 0.2-0.4 million cases of visceral leishmaniasis (VL). 29 VL and 2465 CL cases were reported per year between the years 2003 and 2007 in Turkey (Alvar et al., 2012). 14.587 CL and 207 VL cases were reported between the years 2005 and 2014 in Turkey (Gürel, Yeşilova, Ölgün, & Özbel, 2012).

Two forms of Leishmaniasis are observed in Turkey; *Leishmania infantum*, *L. tropica*, *L. major*, and *L. donovani* cause CL (Serin et al., 2005; Koltas, Eroglu, Alabaz, & Uzun, 2014) and *L. infantum* for VL. CL is highly endemic in southern southeastern Anatolia, whereas VL is endemic along the Aegean and Mediterranean coasts (Özbel et al., 1995; Ok, Balcioglu, Taylan, Ozkan, Alkan, & Özbel, 2002; Volf et al., 2002; Yaman & Özbel, 2004). *P. papatasi* and *P. sergenti* are probable vectors of *L. major* and *L. tropica* in Turkey respectively (Alptekin et al., 1999; Pazarbasi, Alptekin, Luleyap, Kasap, & Kasap, 2006; Volf et al., 2002); also, *P. tobbi* is the proven vector of *L. infantum* reported agent of CL in Turkey (Svobodová et al., 2009).

According to previous studies in Eirenis Region, *P. papatasi* Adler, *P. tobbi* Adler, Theodor et Lourie (1930) was found as the most abundant (71.3%) species while *P.*

sergenti Parrot (1917), the proven vector of *L. tropica* in Turkey, represented only 3% of the sand fly fauna (Alptekin et al., 1999; Volf et al., 2002; Yaman & Özbel, 2004; Simsek et al., 2007). According to the results of the recent investigations in this region, *L. infantum* Nicolle (1908) was collected from *P. tobbi* specimens for the first time (Svobodová et al., 2009). All these data show that further studies on the population distribution of sand fly species should be performed to reveal the risk of CL and VL in Turkey.

Data was taken from M.Sc. thesis of the first author between the years 2005 and 2007 and distribution maps were determined by using ArcGIS 10 (ESRI, 2011). For this purpose, inverse distance weighted (IDW) method was used. Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. This method assumes that the variable being mapped decreases in terms of the influence with distance from its sampled location (Philip & Watson, 1982; Watson & Philip, 1985).

This paper gives the results of an investigation to determine the species distribution in Çukurova Plain, Southern Anatolia, Turkey. Thus, it will give information about the possible distribution of Leishmaniasis in Çukurova Plain that will be effective for the control of CL and VL.

2. Material and Methods

2.1. Study area

Field studies were conducted in Çukurova Plain, South Anatolia from May to October between the years 2005

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and 2007. Sampling was made in 53 villages that are shown in Table 1 and Fig. 1.

Table 1: Sampling stations' features

Village	Coordinates		Height
Kulak	N 36 47 37.7	E 34 52 01.8	1 m
Bahşiş	N 36 49 36.2	E 34 53 08.6	6 m
Yaramuş	N 36 49 19.1	E 35 02 50.0	8 m
Çağbaşı	N 36 51 53.9	E 35 03 53.4	15 m
Yenice	N 36 58 39.2	E 35 02 57.4	42 m
Bebeli	N 36 38 24.7	E 35 29 30.0	7 m
Adalı	N 36 38 04.8	E 35 32 33.0	7 m
Yemişli	N 36 39 18.6	E 35 21 31.0	9 m
Eğriağaç	N 36 46 40.8	E 35 26 50.4	9 m
Cine	N 36 47 49.0	E 35 15 37.9	10 m
Hacı Hasan	N 36 43 37.5	E 35 16 34.2	10 m
Kızıлтаhta	N 36 45 01.3	E 35 34 43.5	16 m
Yalnızca	N 36 46 31.6	E 35 24 53.8	18 m
Doğankent	N 36 50 51.9	E 35 20 19.0	20 m
Dedepınarı	N 36 55 36.6	E 35 28 56.4	4 m
Ziyalı	N 36 49 35.4	E 35 34 22.4	18 m
Yumurtalık	N 36 46 55.4	E 35 47 44.5	22 m
Zeynepli	N 36 44 14.4	E 35 34 43.5	25 m
Çiftlikler	N 36 58 52.6	E 35 52 34.5	26 m
Narlık	N 36 55 03.6	E 35 51 14.3	48 m
İsalı	N 36 55 11.9	E 35 43 04.9	63 m
Belören	N 36 48 42.2	E 35 33 20.9	99 m
Baklalı	N 37 02 11.2	E 35 38 16.6	124 m
Çelemlı	N 36 50 48.1	E 35 39 02.4	162 m
Küçük Tüysüz	N 37 02 57.0	E 36 05 31.4	65 m
Çağsak	N 37 09 12.8	E 36 20 02.9	184 m
Tehci	N 37 09 14.8	E 36 20 01.9	192 m
Sarımazı	N 36 58 21.5	E 35 58 32.4	222 m
Dutlupınar	N 37 01 39.7	E 36 01 03.7	222 m
Tüysüz	N 37 01 56.4	E 36 04 41.5	228 m
Akçakoyunlu	N 37 11 15.4	E 36 25 13.3	373 m
Düziçi	N 37 15 52.6	E 36 28 27.1	530 m
Kesmeburun	N 37 15 52.9	E 36 28 27.0	530 m
Karakütük	N 37 24 40.1	E 36 07 15.8	203 m
Sofular	N 37 22 53.9	E 36 14 20.0	300 m
Kızıyusuflu	N 37 19 54.8	E 36 12 36.7	373 m
Aydınlar	N 37 21 35.5	E 36 00 45.1	45 m
Bucak	N 37 26 54.4	E 35 54 19.5	66 m
Döşeme	N 37 25 28.1	E 35 51 59.2	175 m
Güneri	N 37 26 45.9	E 35 46 52.8	235 m
Kızıllar	N 37 28 43.8	E 35 48 49.7	351 m
Gedikli	N 37 30 10.1	E 35 51 40.5	381 m
Mercimek	N 37 06 19.1	E 35 47 31.1	33 m
Hamamköy	N 37 19 08.7	E 35 49 02.8	45 m
Tumlu	N 37 08 49.9	E 35 42 26.3	66 m
Koyunevi	N 37 17 21.3	E 35 39 23.6	146 m
Camili	N 37 20 19.5	E 35 36 38.5	181 m
Tepecikören	N 37 21 50.8	E 35 37 38.9	189 m
Otluk	N 37 18 05.2	E 35 31 05.3	237 m
Gökbüket	N 37 07 39.1	E 35 32 48.6	244 m
Aydın	N 37 24 35.6	E 35 35 43.8	278 m
Zerdali	N 37 24 18.2	E 35 37 51.2	292 m
Tepeçaylak	N 37 03 33.6	E 35 03 34.7	188 m

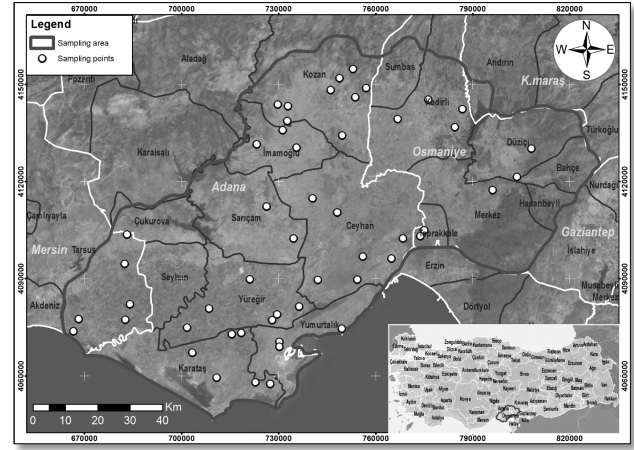


Figure 1: Map of sampling stations

2.2. Collection methods

Sand flies were collected monthly from May to October between 2005 and 2007 using one Centre for Disease Control (CDC) light trap (John W. Hock, USA) and one CO₂ light trap (0.5 kg dry ice) in every location placed in yards and set up about 1.5 m above the ground for the whole night (between 20:00-06:00 hours). Four sticky paper traps (20 x 30 cm papers coated with castor oil) were rolled up and placed in the holes of the wall that surrounds the animal shelters at every location. Moreover, indoor collections were performed by using mouth aspirators in the houses at every location.

2.3. Sand fly identification

Specimens collected from each trap were stored in 96% alcohol for morphological identification and further molecular studies. Identification was based on the morphology of the male genitalia and female spermatechae and pharynges using the keys of Theodor (1958), Artemiev (1980), Lewis (1982), and Killick-Kendrick et al. (1991).

2.4. Inverse distance weighted (IDW)

The Inverse Distance Weighing (IDW) interpolator is an automatic and relatively easy technique. It requires very few parameters, such as search neighborhood parameters, exponent and eventually smoothing factor (Hessl, Miller, Kernan, Keenum, & McKenzie, 2007). The IDW directly applies the assumption that the un-sampled locations were average weighted from the known data points (Mitas, Mitasova, & Brown, 1999) as in the following formula:

$$Z_j = \frac{\sum_{i=1}^n \frac{Z_i}{(h_{ij} + \delta)^\beta}}{\sum_{i=1}^n \frac{1}{(h_{ij} + \delta)^\beta}} \quad (1)$$

Where Z_j is the value from an unsampled location, Z_i are the known values, β is the weight and δ is a smoothing parameter. The separation distance h_{ij} between a known and unknown point is measured with euclidean distance:

$$h_{ij} = \sqrt{(\Delta x)^2 + (\Delta y)^2} \quad (2)$$

where Δx and Δy are the distances between the unknown point j and the sampled one i according to reference axes.

IDW was determined by using ArcGIS 10 (ESRI, 2011).

3. Results

A total of 156 *P. papatasi*, 314 *P. tobbi*, and 84 *P. sergenti* species were collected. Of the collected total, *P. tobbi* was found to be the most abundant (56.7%) species whereas *P. papatasi* the second abundant (28.2%) and *P. sergenti* third abundant (15.1%) of the total collected three species (Table 2).

Table 2: Abundance of the collected three species

Species	Abundance (%)	Specimen	n females	Female ratio (%)	n males	Male ratio (%)
<i>P. papatasi</i>	28.2	156	73	46.8	83	53.2
<i>P. tobbi</i>	56.7	314	138	43.9	176	56.1
<i>P. sergenti</i>	15.1	84	49	58.3	35	41.7
Total		554	260		294	

The species distribution in Çukurova Region is determined using IDW. The outcome of IDW and the results for *P. papatasi*, *P. tobbi*, and *P. sergenti* are given at figures below separately.

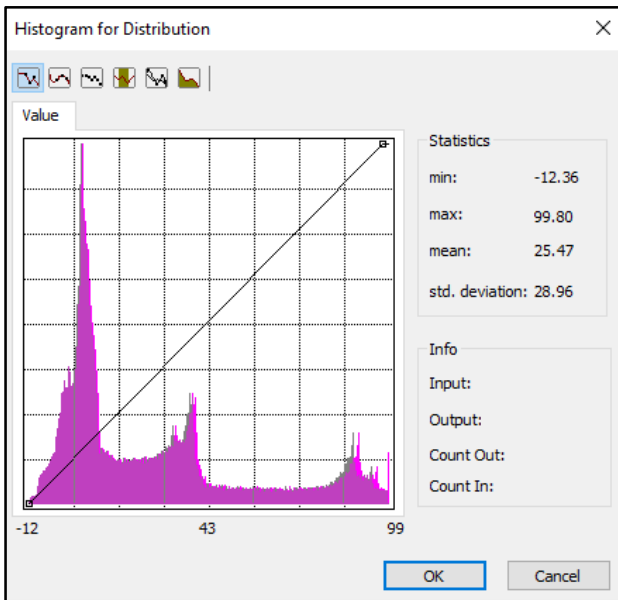


Figure 2: IDW results for *P. papatasi*

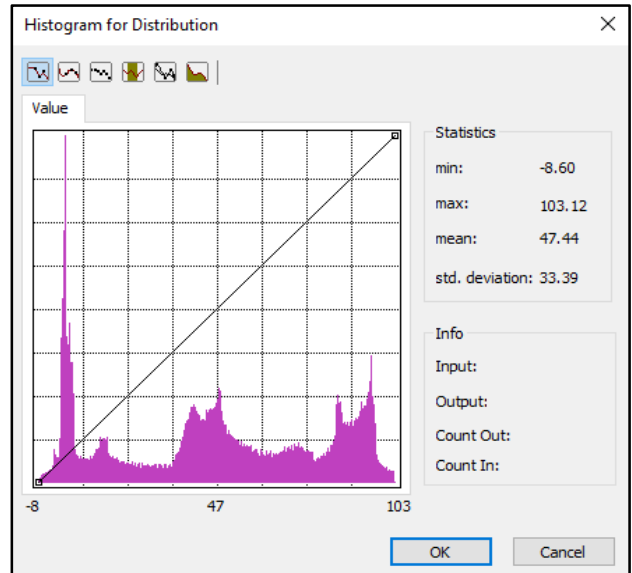


Figure 3: IDW results for *P. tobbi*

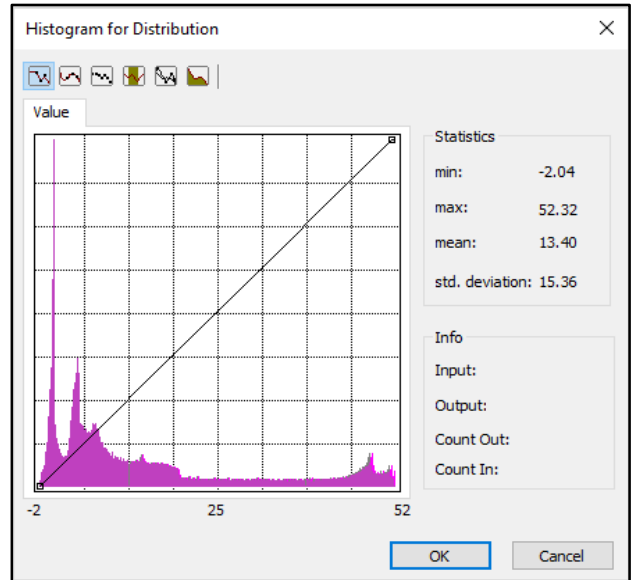
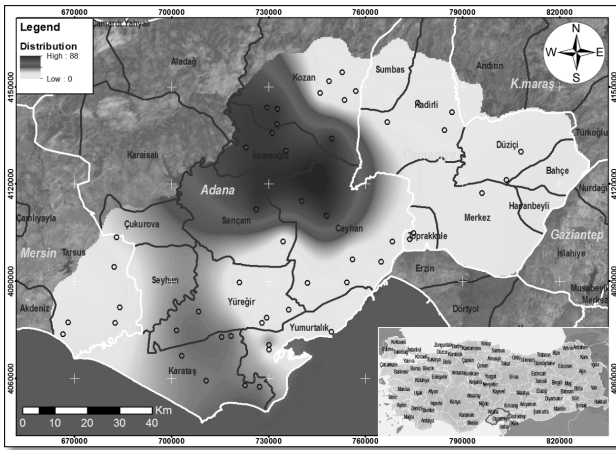
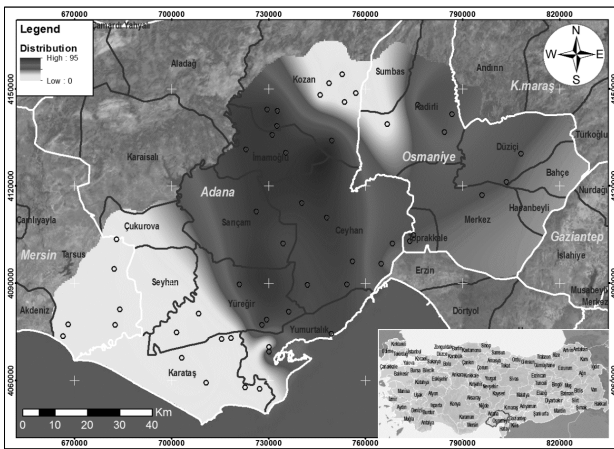
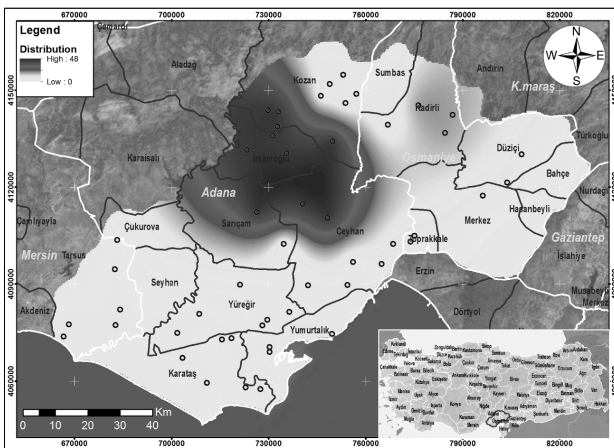


Figure 4: IDW results for *P. sergenti*

According to the graphs and statistics, above minimum, maximum, mean, and standard deviation for each species are given. Standard deviation for all three species is very high due to small sampling size; however, this does not affect the IDW. As shown in Fig. 2 and Fig. 3, there are three main peaks that means the population of *P. papatasi* and *P. tobbi* are mainly distributed in three main points. On the otherhand, *P. sergenti* population is mainly distributed in two main points as shown in Fig. 4.

Figure 5: Distribution modeling using IDW for *P. papatasi*Figure 6: Distribution modeling using IDW for *P. tobbi*Figure 7: Distribution modeling using IDW for *P. sergenti*

4. Discussion

Phlebotomine sand flies are abundant and widespread in southern Anatolia with at least sixteen species present in the area. More importantly, all proven or suspected vectors of leishmaniasis in Turkey are also present (Alptekin et al., 1999; Volf et al., 2002; Yaman & Ozbel, 2004; Toprak & Ozer, 2005).

Simsek et al. (2007) disguised the distribution and altitudinal structure of sand flies in southern Anatolia, Turkey. According to the results 3172 sand flies were collected. In Çukurova Region, 105 sand flies were collected from Osmaniye and 1092 sand flies were collected from Adana. However, the locations were not

identified. Therefore, a comparison of the distribution could not be made with our study.

Svobodova et al. (2009) worked at the western and eastern part of Çukurova Region, Turkey. According to the results, *P. tobbi* was dominant at the western (82.56%) and the eastern (81.34%) part of Çukurova Region, Turkey. Sampling areas were determined according to CL information of local health centers. In comparison to our results, *P. tobbi* shows the same results. According to the distribution modeling (see Fig. 6) of *P. tobbi*, two significant areas were identified. The western part where Tepecikören, Zerdali and Camili are the centers and eastern part where Boyali is the center. These results reflect similarity with the study of Svobodova et al. (2009). Moreover, *P. papatasi* was determined only at the western (12.16%) part of Çukurova Region, Turkey. This result reflects overlap with our study. *P. papatasi* is mostly distributed at the western part of Çukurova Region, Turkey. *P. sergenti* was determined at the western (0.8%) and at the eastern (10.77%) part of Çukurova Region, Turkey. According to our study *P. sergenti* is more distributed at the western part than at the eastern part of Çukurova Region, Turkey.

Kavur and Artun (2017) map the risk areas for each sand fly species using remote sensing images in İmamoğlu, Adana. According to the results, three probable leishmaniasis vectors (*P. tobbi*, *P. neglectus/syriacus*, and *P. perfiliewi*) were identified. The spatial probability of *P. tobbi* was higher than the other species. According to the observation, the southwest part of İmamoğlu district had a high CL risk. The results of Kavur and Artun (2017) support the results of our study.

Kavur and Artun (2018) displayed the prevalence and incidence between 2009 and 2014 in Adana using GIS. According to the results the CL prevalence (2011-2014) and incidence (2011-2014) were found to be highest in İmamoğlu. This result reflects our distribution modeling for proven leishmania vectors.

In conclusion, the poor dispersal ability let to determine the possible diversity of *P. papatasi*, *P. tobbi*, and *P. sergenti* species. Nevertheless, the sampling size was small but an IDW mapping could be performed. Thus, it will give a possible distribution for Leishmaniasis risk areas in Çukurova Region. As shown in Fig. 5, Fig. 6, and Fig. 7, the dispersal center is İmamoğlu where the CL disease is common. In addition, it is important to notice that Leishmaniasis is transmitted with female sand flies. With these results, it can be decided which areas for disease control can be done more effectively.

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