International Research Journal of Public and Environmental Health Vol.5 (6),pp. 83-89, September 2018
Available online at https://www.journalissues.org/IRJPEH/
https://doi.org/10.15739/irjpeh.18.012

ISSN 2360-8803

Original Research Article

Modelling local and regional spatial distribution patterns of *Toxocara canis* eggs using spectral indexes

Received 9 July, 2018 | Revised 24 August, 2018 | Accepted 1st September, 2018 | Published 15 September, 2018

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Soil contaminated by *Toxocara* spp. eggs is considered as one of the main infection sources of Toxocariasis worldwide. In this study, we developed with a maximum entropy model (MaxEnt) a local and regional simulation for predicting the spatial patterns of *Toxocara* spp. eggs in soil in urban parks of Mexicali, Baja California Mexico, based on a remotely sensed Normalized Difference Vegetation Index (NDVI), an indicator of vegetation greenness, Normalized Difference Water Index (NDWI) and Earth Surface Temperature (EST). 56 public parks were sampled during a year (2016-2017). Flotation technique was used for the determination of *Toxocara* eggs contamination in soil samples. 54% of the parks were positive to helminths eggs. The regional model includes all urban areas, the local model represents one single park. Our findings indicate that NDVI is the variable with more contribution for the survival of the parasite. The probability of favorable conditions for the existence of *Toxocara* spp. is 89% in green spaces. It is documented that *Toxocara* eggs survive up to two years in humid, clayey and grassy conditions, being sensitive to direct sunlight. Due to the climate of the city of Mexicali, it is thought that there is a minimum presence of this organism. However, *Toxocara* spp. has been reported in July, where temperatures exceed 35 °C. This validates that vegetation, regardless of temperature contributes in a greater measure to its presence.

Key words: Soil contamination, spectral indexes, *Toxocara* spp., maximum entropy, parks.

INTRODUCTION

Zoonoses are diseases and infections that are transmitted under natural conditions between animals and humans (WHO, 2017). The World Health Organization identifies zoonoses as emerging threats and describe them as previously occurring phenomena that have an increasing trend and expansion in geographical, host or vector range. More than 60 % of all emerging infectious diseases are from zoonoses (Mackenzie, 2013). Fifty zoonoses are transmitted to humans by dogs, one of the most common is toxocariasis caused by *Toxocara* spp. (Gallardo, 2012). The via of infection is by accidental ingestion of eggs dispersed in the environment (Archelli, 2008). The main source of human exposure to this parasite is through fecal contamination of the environment by dogs, cats and wild animals (Kazacos, 2000). Several studies have reported that soil is the most common source of infection (CDC, 2017). *Toxocara* spp. eggs can be found in the soil of a large part of the planet; they appear in 2-88% in soil samples collected in several countries and regions, the high temperatures and humidity of the tropics favor the transmission of the species (ISUCFSPH, 2016). In public parks of Mexico City, high contamination with *Toxocara spp.* eggs was reported due to the high density of stray dogs, with frequencies of 60% (Romero Núñez, 2013), which coincides with the frequency reported in 2007 in the city of Mexicali, of 62.5% (Tinoco, 2007).

Since the primary sources of exposure for children are the contaminated parks and playgrounds, this study was

conducted to create two spatial distribution models using maximum entropy to predict the pattern from a single park within a neighborhood to the distribution throughout the city with the results obtained from the park´s soil survey during 2016-2017.

MATERIALS AND METHODS

According with results obtained from the park´s soil survey during 2016-2017 from February to May there was a 3.7 times higher risk of finding eggs of *Toxocara* spp. in Mexicali. The models were created with information corresponding to this period. MaxEnt software was used to perform the models, which estimates the probability of unknown distribution of a species (Phillips, 2006).

The maximum entropy model, MaxEnt®, can perform spatial prediction models by merging presence-only data (Matyukhina, 2014). The environmental variables most closely associated with the presence of a species can be used to estimate the potential geographic distributions of the species. Compared to other methods, MaxEnt tends to produce better models for distribution predictions and has been widely used to predict possible distributions of nematodes (Baldwin, 2009).

Study area and sampling design

Mexicali is a Mexican city, capital of the state of Baja California, located in the northwest corner of the Mexicali Valley on the border with the United States, at the coordinates 32 ° 39 '48 "north latitude, it´s the northernmost city of Mexico and Latin America. The climate is a warm desert climate (Bwh), according to the Köppen climate classification. The temperature is rarely less than 4 °C or more than 48 °C, has low annual precipitation level (77 mm). From February the maximum temperatures are between 20 ° C and 27 ° C to May with maximum temperatures between 35 ° C and 40 ° C. In Mexicali exist 323 public parks, most of them have sandy clay loamy soil texture, some parts have grass, trees, a small square and playgrounds. People use the park to walk the dogs, take the kids to the playground and the stray dogs live part of the day there. The parks have a maintenance routine of three days per week, which consist to water the grass and trees, remove garbage and feces. Not all are in the best conditions and it depends of the vandalism and security of the neighborhood.

Local model

(a) Location

The selection of the park was according to number of positive soil samples and the security of the neighborhood. The urban park selected is within Nueva Esperanza neighborhood (Figure 1).

(b) Presence data

10 positive soil samples of *Toxocar*a spp. eggs were distributed around the park

(c) Environmental variables

On-site sampling was carried out to create maps of temperature, texture and soil moisture. The data obtained were interpolated using the IDW method in ArcGIS.

Temperature layer: 56 points were distributed in the park with and without grass zones. The temperature of each point was recorded every hour. The sampling lasted 12 hours.

Soil moisture layer: 56 soil samples from each point were taken to the laboratory to measure by gravimetry the soil moisture content (AS-02 NOM-021-RECNAT-2000).

Soil texture layer: As the previous two layers, a sample of soil was taken from the 56 points. The Bouyoucos method was used to determine the soil texture (NOM-021-RECNAT-2000, 2000).

Regional model

(a) Location

City of Mexicali, including Santa Isabel and Progreso Neighborhoods. Figure 2.

(b) Presence data

For the presence data was used the location of the 28 urban parks that were positive to *Toxocara* spp. eggs on the soil survey realized during 2016-2017.

(c) Environmental variables

14 Landsat 8 Sensor OLI satellite images were downloaded from February- May 2016 and February-May 2017, to obtain the spectral indexes from reflectance data at atmospheric top (TOA). These indicators were used because they have been shown to have a better prediction (Jiang, 2014) than information downloaded from environmental databases.

Normalized difference vegetation index (NDVI)

Is an index used to estimate the quantity, quality and development of vegetation based on the measurement, by means of remote sensors commonly installed from a space platform, of the intensity of the radiation of certain bands of the electromagnetic spectrum that the vegetation emits or reflects.

Water Index of Normalized Difference (NDWI)

It provides information of the water stress of vegetation
It uses the combination of reflectance at 0.86 μm and 1.24 μm, eliminating the variations induced by the internal structure of plant tissues and their dry matter content, improving the precision in determining the water content of the vegetation.

Earth surface temperature (EST)

The determination of the temperature of the terrestrial surface (ST) from the infrared images supplied by the artificial satellites. For the calculation of the temperature it

Figure 1: Contaminated urban park where soil samples were taken to measure temperature, texture and humidity

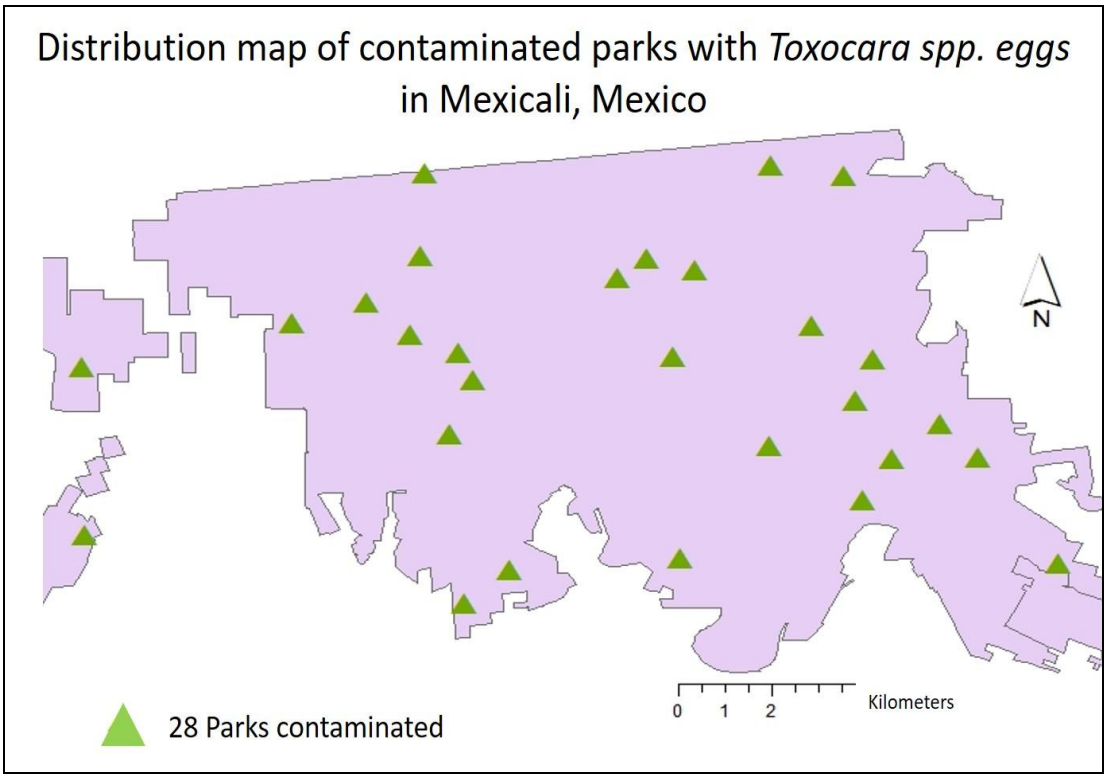

Figure 2: Map of 28 parks used as presence data for the regional model with MaxEnt according with the results of soil´s survey 2016-2017

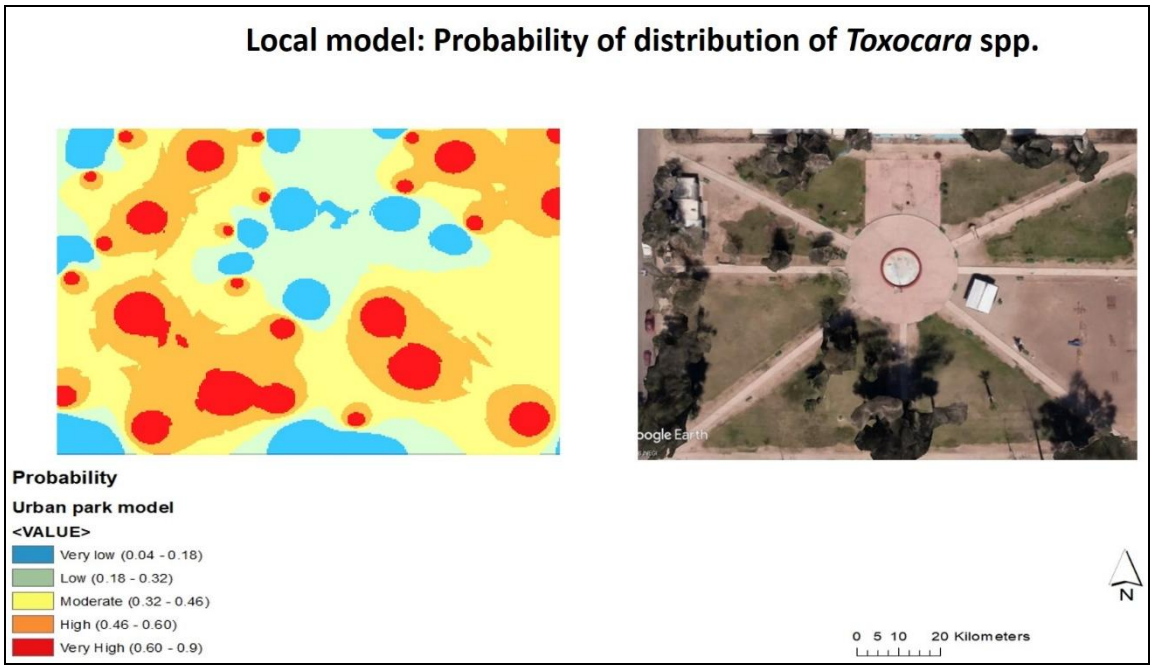

Figure 3: Distribution map for local model. This map was constructed using presence locations from 10 samples contaminated inside the park with *Toxocara* spp. eggs as training data for MAXENT. The map shows potential presence ranging from 0.0 (low) to 1.0 (high). The high and very high probabilities correspond to grass zones.

is necessary, NDVI, Band 10 TIR and Band 11 TIR (LANDSAT 8) (USGS, 2018).

MaxEnt execution

MaxEnt version 3.3.1 (Phillips, 2006) was used to perform the models with an output format, logistic and data analysis, auto features. Once the program was executed, the environmental variables that contribute 0% to the model were discarded through the Jack-knife analysis.

Model evaluation

For the evaluation of the model, the AUC index (area under the curve) was used. The AUC statistic was obtained with the same MaxEnt program. The AUC statistic takes values between 0 and 1, where values less than 0.7 indicate that the quality of the model is poor, 0.7-0.8 the quality of the model is good, 0.8-0.9 the quality of the model is very good and values greater than 0.9 indicate excellent model quality (Mezaour, 2005).

RESULTS

During 2016-2017 a cross-sectional epidemiological study was conducted in 56 public parks of Mexicali, the general frequency of contaminated parks with helminths eggs was 54% (30/56). The specific parasite frequency by park was *Toxocara* spp. with 50% (28/56), followed by *Ancylostoma* spp. 3.5% (2/56). In relation to the type of soil, 8.1% of the positive samples were detected in bare soil, while 18.6% were detected in soil with grass. It was 2.5 times more likely to find parasites in grassy soil than in bare soil.

Local model

The local model was developed with 10 soil contaminated samples of the urban park as presence locations. The values of the AUC model (area under the curve) are 0.827 and 0.678 for the training data and the test data, respectively. The p values are very low (p = 0.0001), which indicates good predictions. The Figure 3 shows clear concentrations of high potential presence in the areas with high humidity level, that corresponds to the grass zones.

The environmental variables used to model potential presence was humidity, texture and temperature. The jackknife test demonstrated the variable with greatest contribution was the humidity with 61.4%, followed by the texture, the temperature has no apparent contribution (Table 1 and Figure 4). Areas with grass are most likely to have *Toxocara* spp. given the properties of sandy clay loam soil texture to conserve moisture.

Regional model

The regional model was developed with 28 contaminated parks around the city sampled during 2016- 2017 as presence locations. The values of the AUC model (area under the curve) were 0.914 and 0.882 for the training data

Table 1. Analysis of variable contributions for local model

Variable	Percent Contribution	Permutation importance
Humidity	61.4	68.8
Texture	38.6	31.2
Temperature	0	0

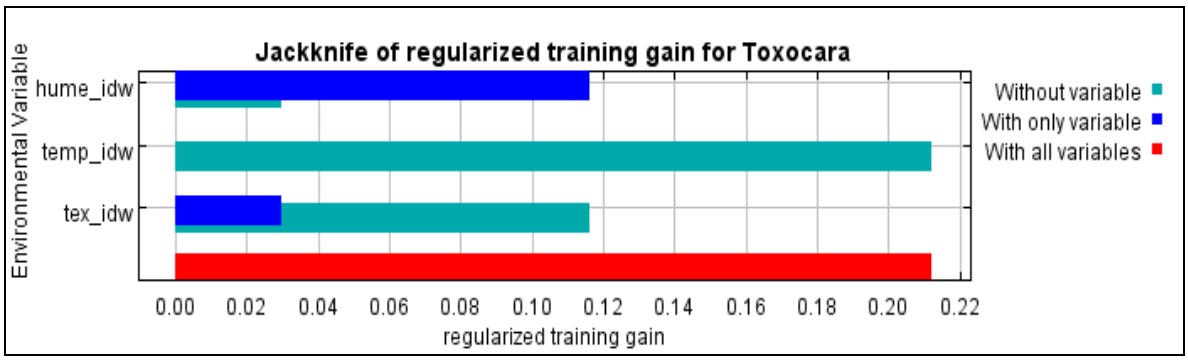

Figure 4: Jackknife evaluation of the local model with MAXENT pondering the relative importance of predictor environmental variables for *Toxocara* spp**.**

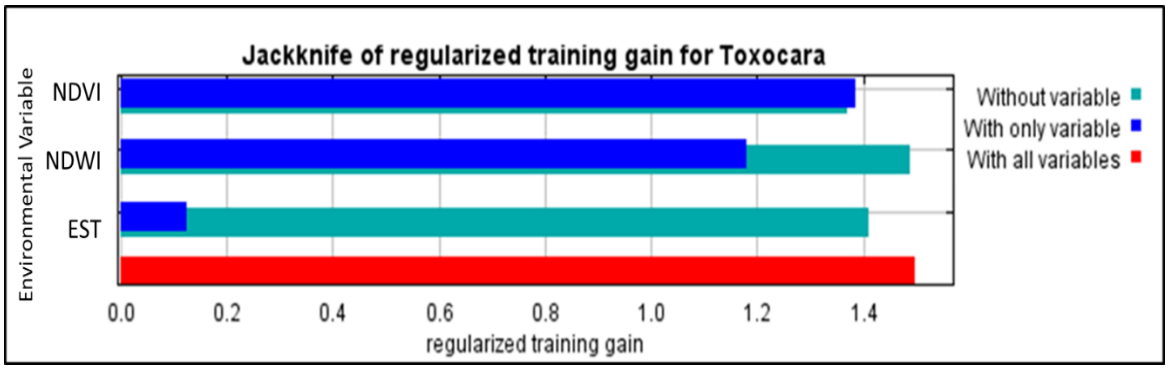

Figure 5: Jackknife evaluation of the regional model with MAXENT pondering the relative importance of predictor environmental variables calculated with spectral indexes NDVI, NDWI and EST

Table 2. Analysis of variable contributions for regional model

Variable	Percent contribution	Permutation importance
NDVI	88.8	84.6
LST	8.7	14.7
NDWI	2.4	0.7

and the test data, respectively. The values of p are very low (p = 0.0001), which indicates very good predictions.

The environmental variables were constructed with spectral indexes: NDWI, NDVI and EST.

Applying the Jackknife test (Figure 5) the environmental variable with the highest gain when used alone is NDVI2, which therefore seems to have the most useful information by itself. The environmental variable that decreases the most gain when it is omitted is NDVI, which therefore seems to have the greatest amount of information that is not present in the other variables (Table 2).

Prediction map

The map shows the potential distribution of soil contaminated by *Toxocara* spp. eggs that has been predicted by MaxEnt. The highest level of probability (P = 0.89) for the distribution of soil contamination slightly

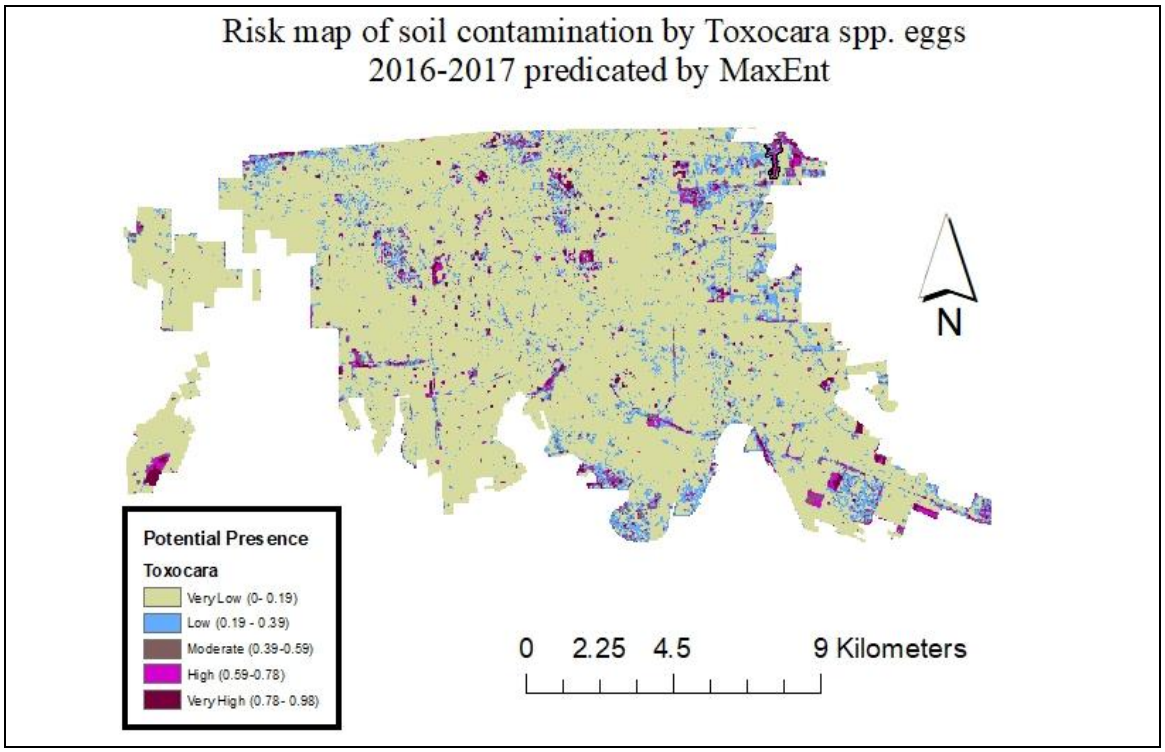

Figure 6: Risk map for regional model. This map was constructed using presence locations from 28 contaminated parks with *Toxocara* spp. eggs sampled during 2016-2017 as training data for MAXENT. The map shows potential presence ranging from 0.0 (low) to 1.0 (high).

covers the entire city, especially in green spaces (Figure 6).

DISCUSSION

Results of this study at regional and local level indicate that spatial variability in vegetation cover (NDVI) and soil moisture influence the distribution of *Toxocara canis* eggs and its survival. In the urban area of Mexicali, the probability of favorable conditions for the existence of *Toxocara* spp. eggs is 89% in green spaces, this is consistent with results from other studies which show greatest contributions were registered at residential areas, forests and green areas, and rainfall (Giacometti, 2000).

Rainfall plays an important role in horizontally distributing *Toxocara* spp. eggs throughout the soil (Holland, 2005). Despite the low rainfall and high temperatures of Mexicali, the eggs can survive in parks soil because are under a controlled microclimate, the water supply is constant, it would be equivalent to the rainfall variable in other studies.

Soil characteristics may affect survival time of *Toxocara* spp. eggs (Gao, 2017). In Mexicali, the soil of the parks is sandy clay loam, this balances water permeability and water and nutrient retention, some areas have grass and others do not, which favors different temperature and moisture zones in the park itself. Moisture is needed by the eggs to prevent desiccation or dehydration. From February to May temperatures vary between 21 ◦ C and 35 ◦ C. In Philippines revealed that *Toxocara* spp. eggs were most prevalent in less acidic, relatively high temperature (mean 31.54+-2.76) and high moisture soil conditions (Vachel, 2014). (Hotez, 2013) reported that 20°C–30°C is suitable for eggs embryonation. Another study suggests that elevated temperatures accelerated the development as well as the degradation of eggs of *Toxocara* spp. whereas the range in humidity was directly correlated with egg development (Gamboa, 2005)

Conclusion

The purpose of measuring at the local scale was to test the results of the regional model using spectral indexes, where the NDVI had a greater contribution. The parks with grass have a lower temperature and higher humidity than bare soil, in addition to the presence of trees and urban furniture generates shadows in some areas, which serves as protection from direct sunlight, favoring all conditions for the survival of the parasite. It is important to mention that this study is to know possible areas of risk, but it does not mean that they are infected.

This shows that *Toxocara* spp. eggs survival varies from place to place due to changes in the amount of vegetation

cover. We conclude that landcover as measured by the remotely sensed normalized difference vegetation index (NDVI) can be used to track other parasites on a spatial-temporal scale.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

REFERENCES

Archelli S (2008). Toxocara y Toxocariosis. Acta bioquímica clínica latinoamericana. 42(3), 379-384.

Baldwin RA. (2009). Use of maximum entropy modeling in wildlife research. Entropy. 11 (4): 854–866.

Benito de Pando BP. (2007). Aplicación de modelos de distribución de especies a la conservación de la biodiversidad en el sureste de la Península Ibérica. Geofocus.7:100-119.

CDC. (2017). Toxocara FAQ´s. Centers for disease control and prevention. [On line] https://www.cdc.gov/parasites/toxocariasis/gen_info/faqs.html

Gallardo JS (2012). Infección por Toxocara canis y factores de riesgo en niños de la comunidad agua azul, Estado Yaracuy. Revista de Enfermería y otras Ciencias de la Salud. 5(1): 21-27.

Gamboa M (2005). Effects of temperature and humidity on the development of eggs of *Toxocara canis* under laboratory conditions. J. Helminthol. 79(4): 327-331.

Gao XW (2017). Influence of land use and meteorological factors on the spatial distribution of *Toxocara canis* and *Toxocara cati* eggs in soil in urban areas. Veterinary Parasitol. 233: 80–85.

Giacometti AC (2000). Environmental and serological evidence for the presence of toxocariasis in the urban area of Ancona, Italy. Eur. J. Epidemiol. 16: 1023-1026.

Holland C (2005). Toxocara: the enigmatic parasite. Dublin: CABI Publising. 301p.

Hotez P (2013). "Blue Marble Health"—Neglected Tropical Disease Control and Elimination in a Shifting Health Policy Landscape. PLoS Negl Trop Dis. 7(11): e2570.

ISUCFSPH. (2016). Toxocariasis. Iowa State University Center for Food Security and Public Health. [On line] https://lib.dr.iastate.edu/cfsph_factsheets/134.

Jiang YT (2014). Satellite-derived vegetation indices contribute significantly to the prediction of epiphyllous liverworts. Satellite-derived Ecological Indicators. 38: 72-80.

Kazacos K. (2000). Protecting children from helminthic zoonoses. Contemp Pediatr. 17: 1–24.

Mackenzie JJ (2013). Reservoirs and vectors of emerging viruses. Curr. Opin. Virol, 3:170-179.

Matyukhina DM (2014). Assessing the influence of environmental parameters on amur tiger distribution in the Russian far east using a MaxEnt modeling approach. Achiev. Life. Sci. 8(2): 95-100.

Mezaour A (2005). Filtering Web Documents for a Thematic Warehouse Case Study: eDot a Food Risk Data Warehouse. In W. S. Kłopotek MA, Intelligent Information Processing and Web Mining. Advances in Soft Computing, 31: 269-278. Berlin: Springer.

NOM-021-RECNAT-2000. (2000). Official Mexican standard that establishes the specifications of fertility, salinity and soil classification. Studies, sampling and analysis. 85p. México: Secretariat of Environment and Natural Resources.

Overgaauw PA (2008). Aspects of Toxocara Epidemiology: Human Toxocarosis. Critical Reviews in Microbiol. 23(3): 215-231.

Phillips SR (2006). Maximum entropy modeling of species geographic distributions. Ecological Modeling. 190:231–259.

Romero Núñez CM (2013). Prevalence and Risk Factors Associated with Toxocara canisInfection in Children. The Sci. World J. 2013: 1-4.

Rubio Robles MS (2012). Canine parasites in soil of public recreation areas in Culiacan, Sinaloa, Mexico. International Journal of Infectious Disease. 16(1): e461.

Tinoco LG (2007). Frecuency of *Toxocara canis* Eggs in Public Parks os the Urban Area of Mexicali, B.C. Mexico. Medwell online. 6 (3):430-434.

USGS. (5 de May de 2018). Landsat missions. U.S. Geological Survey. [On line] https://landsat.usgs.gov/using-usgs-landsat-8-product.

Vachel GR (2014). "Toxocara (Nematoda: Ascaridida) and Other Soil-Transmitted Helminth Eggs Contaminating Soils in Selected Urban and Rural Areas in the Philippines,". The Scientific World Journal. 2014: e6.

WHO (2017). Zoonoses.World Health Organization. [On line]: www.who.int/topics/zoonoses/.