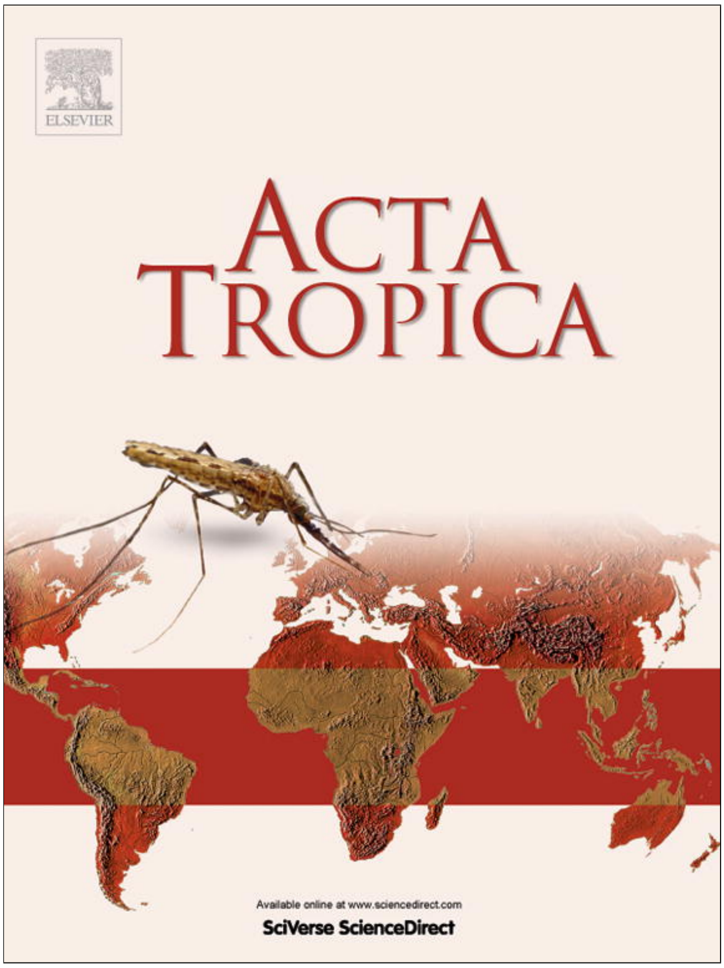
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Landscape determinants of Saint Louis encephalitis human infections in Córdoba city, Argentina during 2010

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ABSTRACT

Saint Louis encephalitis virus (SLEV) is endemic in Argentina. During 2005 an outbreak occurred in Córdoba. From January to April of 2010 a new outbreak occurred in Córdoba city with a lower magnitude than the one reported in 2005. Understanding the association of different landscape elements related to SLEV hosts and vectors in urban environments is important for identifying high risk areas for human infections, which was here evaluated. The current study uses a case–control approach at a household geographical location, considering symptomatic and asymptomatic human infections produced by SLEV during 2010 in Córdoba city. Geographical information systems and logistic regression analysis were used to study the distribution of infected human cases and their proximity to water bodies, vegetation abundance, agricultural fields and housing density classified as high/low density urban constructions. Population density at a neighborhood level was also analyzed as a demographic variable. Logistic regression analysis revealed vegetation abundance was significantly ($p < 0.01$) associated with the presence of human infections by SLEV. A map of probability of human infections in Córdoba city was derived from the logistic model. The model highlights areas that are more likely to experience SLEV infections. Landscape variables contributing to the outbreak were the proximity to places with vegetation abundance (parks, squares, riversides) and the presence of low density urban constructions, like residential areas. The population density analysis shows that SLEV infections are more likely to occur when population density by neighborhood is lower. These findings and the predictive map developed could be useful for public health surveillance and to improve prevention of vector–borne diseases.

1. Introduction

Saint Louis encephalitis virus (SLEV) is a mosquito-borne pathogen which belongs to family Flaviviridae, genus *Flavivirus*. SLEV has an extensive range in the Americas, and has been detected from isolations in mosquitoes, birds and mammals from Southern Canada to Argentina. SLEV is maintained by zoonotic transmission between birds and mosquitoes (Reisen, 2003); humans are considered dead-end hosts of the virus. Less than 1% of SLEV infections are clinically apparent (Tsai et al., 1987). Illness ranges in severity from transient fever and headache to severe meningoencephalitis and death.

In Argentina SLEV is endemic and extensively distributed. Serological evidence of SLEV infections fluctuates within different locations, affecting in some cases 50% of the population (Sabattini et al., 1998; Spinsanti et al., 2001, 2002). SLEV strains have been isolated from humans, *Culex* mosquitoes and wild rodents (Diaz et al., 2006; Sabattini et al., 1998) in Argentina. For this region, the principal vector is postulated to be *Culex quinquefasciatus* and the main avian hosts are Picui Ground Doves (*Columbina picui*) and Eared Doves (*Zenaida auriculata*) (Diaz, 2009; Diaz et al., 2006). However, Passerines bird species may also be involved in transmission (Diaz, 2009). In Córdoba province (central Argentina), where the population has a seroprevalence of 13.9% (Spinsanti et al., 2002), a human encephalitis outbreak caused by SLEV was reported in 2005 with 47 cases and 9 deaths (Spinsanti et al., 2008). In the following years only sporadic cases were registered, but during January to April of 2010 an outbreak occurred in Córdoba city with

Abbreviations: SLEV, Saint Louis encephalitis virus; WNV, West Nile virus; CSF, cerebrospinal fluid; NDVI, Normalized Difference Vegetation Index; LDC, low density urban constructions; HDC, high density urban constructions; GIS, geographic information systems.

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a lower magnitude than the one reported in 2005 (Vergara Cid et al., 2011).

Geographic information systems (GIS) have been extensively used for the surveillance of vector–borne diseases. Studies usually include spatial and temporal data in which environmental factors, landscape, climatic conditions and demography are analyzed in relation to *Flavivirus* dynamics among humans, mosquitoes, and zoonotic hosts (Bradley et al., 2008; Diuk-Wasser et al., 2006; Eisen and Lozano-Fuentes, 2009; Estallo et al., 2008, 2011; LaBeaud et al., 2008). Environmental conditions may regulate virus ecology due to their effect on the mosquito vectors and avian hosts necessary for virus transmission. Landscape attributes seem to have an important effect on West Nile virus (WNV, *Flavivirus*) disease dynamics and ecology by influencing host and vector presence. Therefore, factors such as vegetation abundance have been positively associated with human infections of WNV in urban and rural environments (Liu et al., 2008; Ruiz et al., 2004, 2007). Other environmental factors and land cover types like stream density, road density, slope, open water, agricultural and wetland areas were also classified as risk factors for WNV (Cooke et al., 2006; DeGroote et al., 2008; Liu et al., 2008). In addition, demographic patterns such as housing characteristics, population density, age and income have been associated to WNV human infections (Brownstein et al., 2002; DeGroote et al., 2008; Rochlin et al., 2011; Ruiz et al., 2004, 2007). Shaman et al. (2004) modeled land surface wetness and levels of SLEV transmission in humans, using a dynamic hydrology model in Florida. They found that drought followed by a wetting period is associated with SLEV human cases.

Even though there are numerous spatial and temporal studies related to WNV ecology and infection dynamics, there have been relatively few studies that have analyzed human SLEV infections. Therefore, understanding the patterns of SLEV hosts and vectors in urban environments will help us to identify high risk areas for human infections. The objective of our research is to identify landscape elements associated to the occurrence of SLEV human infections in Córdoba city throughout 2010.

2. Materials and methods

2.1. Study area

Córdoba city is located in the province of Córdoba, in the center of Argentina (31°24′S; 64°11′W), between 360 and 480 m above sea level (Fig. 1). It is an important urban settlement with a surface of 576 km^2 and with a population of 1,330,023 inhabitants as of the 2010 official census. Córdoba lies in a temperate semi-dry climate, with a mean annual precipitation level of 800 mm. The winter represents a markedly dry season, while in summer the most of precipitations occur. The Suquía River along with its creek La Cañada and other numerous water channels run through the city. The urban area is surrounded by agricultural fields which mainly produce vegetables, fruits and soy. The forest patches around the city have been drastically reduced in recent years.

2.2. Study subjects

The serological database used for the current study was obtained from different healthcare centers of Córdoba city that directly sent to our laboratory serum samples from symptomatic individuals who were suspected of *Flavivirus* infections during January to April of 2010. Besides of symptomatic infections, we included asymptomatic infections and study controls (non-infected individuals). The serum samples from these last two groups were also obtained from healthcare centers that had an agreement with our laboratory. People who went to the healthcare centers needed analysis of blood for different reasons and some of their serum was collected (August–September) and sent to our laboratory to detect antibodies against SLEV and other *Flavivirus*. The serological survey included 514 individuals from different areas of the city. To protect privacy, this study was designed as a non-associated anonymous survey, registering only date of sampling and address. Confirmed cases are defined by the presence of specific IgM antibody in cerebrospinal fluid (CSF) or serum plus ≥4-fold increase or decrease in neutralizing SLEV antibody titers in the serum (mainly IgG) between paired samples (obtained at least 1 week apart), while a probable case is defined by the demonstration of SLEV-IgM antibody in serum or CSF (Spinsanti et al., 2008). In this study 21 SLEV cases were classified as probable cases due to the absence of second serum samples.

2.3. Study design

In this study, a case–control design was selected at a household geographical location, considering a buffer area of 0.0225 km^2 (approximately 1.5 blocks) for each sample as the unit of analysis. The spatial scale of this model was based on the assumption that humans become infected by SLEV near their residence. The studied cases included 21 individuals infected with SLEV (with IgM and neutralizing antibodies). Study controls included 120 non-infected individuals (absence of antibodies against SLEV) randomly selected from the total of samples serologically analyzed for the year 2010. The explanatory variables for the analysis were chosen for being relevant to vector and host ecology for *Flavivirus* infections. Most of variables were Euclidean distances to important landscape elements like main vegetated areas, lotic and lentic bodies of water and agricultural fields, while the other two were absence/presence of high/low density urban constructions. We included agricultural fields as a variable because the production is under irrigation conditions, which generate moisture for mosquito breeding. Grech et al. (unpublished data) as well as Pires and Gleiser (2010) made mosquito and larvae samplings in agricultural fields around Córdoba city, and they found low to medium larvae density in irrigation canals.

Population density was included as an extra variable at a neighborhood level where presence and absence of cases were registered.

2.4. Data collection and processing

The satellite-derived variables were obtained from Landsat 5 (L5 TM) path/row 229/82. The satellite image, dated from February 2010 and it was obtained from the Argentine Space Agency (CONAE) catalog by academic cooperation. ENVI (Environment for Visualizing Images, Research Systems) 4.2 software (ENVI RS, 2004) was used for image processing. The images were georeferenced using a georeference image from the GLCF (Global Land Cover Facility). Subsequently, a subset area of 851 km^2 including Córdoba city and its surroundings was generated. From this image, five landscape elements were extracted using the software IDRISI Andes (Eastman, 2006). Supervised maximum likelihood classification was applied to produce agricultural fields and housing density classified as two categories: high/low density urban constructions. Lotic water bodies (Suquía River, La Cañada creek) and lentic water bodies (water channels and ponds) were obtained by a combination of maximum likelihood classification and georeferencing using Google Earth imagery and maps provided by the Municipality of Córdoba as reference. The Normalized Difference Vegetation Index (NDVI) was also calculated for the city and its surroundings. A threshold value of NDVI > 0.3 was selected according with literature where a marked positive correlation was observed between mosquitoes abundances of several species and places with NDVI > 0.3 (Lopes et al., 2005; Ozdenerol et al., 2008). Maps with Euclidean distance to the nearest source cell

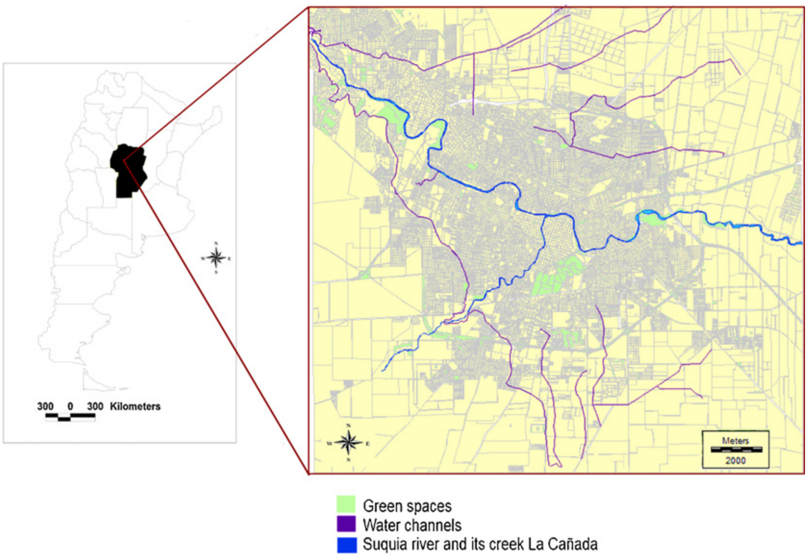

Fig. 1. Map of Córdoba city, Argentina.

were generated for lotic water bodies, lentic water bodies, mixed water bodies (lotic and lentic water combined), agricultural fields and pixels with NDVI > 0.3. The variables representing housing density were used as separately Boolean layers: high density urban constructions (HDC) and low density urban constructions (LDC).

The cases and controls used in the analysis were geocoded by Google Earth 6.2 employing the residential address. A buffer zone of 5 × 5 pixels was delimitated around each location.

Finally, human population density was estimated for each neighborhood using 2001 census data available for Córdoba city at neighborhood level (INDEC, Censo Nacional de Población, Hogares y Viviendas, 2001), in combination with the results of the serological survey, and symptomatic patients registered in 2010. Neighborhoods were classified as tracks with cases if there was at least one resident with IgM antibodies against SLEV. Neighborhoods where there was no evidence of SLEV infections (absence of neutralizing antibodies) were classified as tracks without cases. The population density for each neighborhood was calculated using the number of inhabitants and the area it covered according to a map with the delimitation of neighborhoods from the Municipality of Córdoba.

2.5. Statistical analysis

Logistic regressions were carried out using the software Infostat v.2010 (Di Rienzo et al., 2010) and IDRISI Andes applying the case–control serostatus of human dataset as a dependent variable. A map of probability of SLEV infection was generated in IDRISI Andes estimating the influence of each variable on the occurrence of infections. The relative operating characteristic (ROC) was calculated as an index of the overall fit of the model. Also, sensitivity (percent of positive testing sites correctly classified), and specificity (percent of negative testing sites correctly classified) were computed for the model. Data of all variables was exported from IDRISI Andes to Infostat in order to run logistic regressions with $p < 0.05$. To minimize collinearity, variables with Pearson's correlation coefficient >0.70 were either combined or excluded from further analysis.

For the population density variable, a Kruskal–Wallis test ($p < 0.05$) was used for case–control analysis.

Table 1
Final logistic regression model for SLEV human risk.

Variable	Coefficient	Wald statistic	p
Distance to pixels with NDVI > 0.3	−0.01	9.72	0.0018
Distance to agricultural fields	3.5×10^{-4}	2.59	0.1076
Low density urban constructions	2.49	2.73	0.08

The spatial implementation of this model in IDRISI Andes was used to produce the SLEV human predictive map.

3. Results

In this study, we developed a predictive map reflecting suitability of infection's occurrence by a logistic regression model. Initially, the predictive variables were tested by a stepwise procedure to determine which environmental variables maximized the fit of the model. There was negative correlation between HDC and LDC (Pearson's correlation coefficient = −0.88). So in order to reduce collinearity, only LDC was used due to a better response in the stepwise procedure. The proximity to lotic, lentic and mixed water bodies were not associated to SLEV cases and were excluded from the final model. The best fit model included three variables: distance to pixels with NDVI > 0.3, distance to agricultural fields and low density urban constructions. Distance to pixels with NDVI > 0.3 was the most associated to high risk tracks and the only one significantly related to human SLEV infections (Table 1).

The distribution of SLEV human cases in Córdoba city is shown in Fig. 2A. In the predictive map of SLEV infections (Fig. 2B), the proximity to pixels with NDVI > 0.3 was linked to the occurrence of human cases while proximity to agricultural fields tends to have the opposite effect on the model (Table 1). Despite non-significant at $\alpha = 0.05$, the presence of low density urban constructions seems to be associated to SLEV cases (Table 1), while high density urban constructions would have the opposite effect as observed during the stepwise procedure with a negative coefficient, and also with the negative correlation with LDC. This was also reflected in the predictive map, where the downtown area and other areas with predominance of high buildings were classified with low probabilities of infection. The model accuracy was evaluated by ROC, sensitivity and specificity (Table 2), obtaining an acceptable fit of the model.

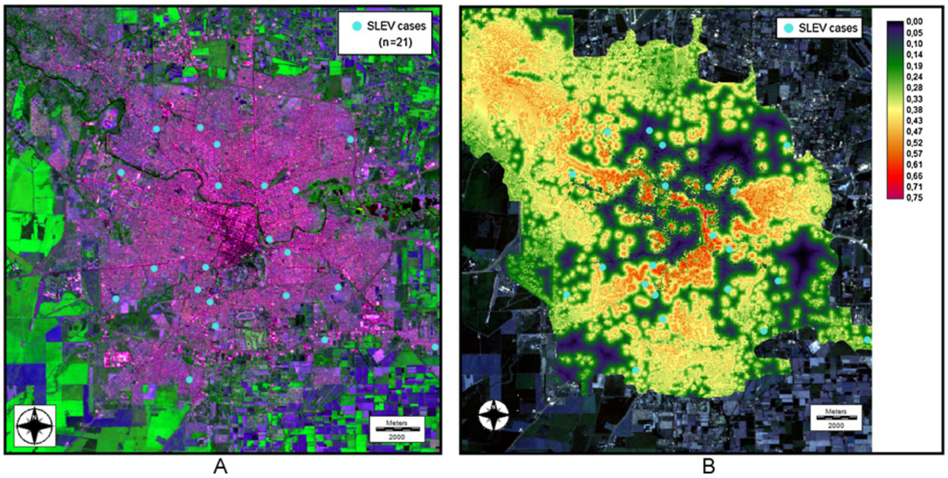

Fig. 2. Distribution of SLEV cases and predictive map of infections. (A) Distribution of SLEV cases in Córdoba city during 2010. The Landsat TM false color image is a RGB composite of bands 7/4/2 that enhances vegetation in green and urban areas in magenta gradient. (B) Map of probability of SLEV human infections based on the final logistic regression model. The probability of SLEV infection occurrence ranges from 0% to 75%. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Overall fit of the model.

Analysis	Value
Sensitivity (%)	88.83
Specificity (%)	81.71
ROC	0.74

ROC, relative operating characteristic.

For the population density analysis the results revealed that infections are more likely to occur when population density is low. The population density ranged from 9 to 278 inhabitants per hectare among neighborhoods. There was a statistically significant difference ($p = 0.04$) in mean population density by neighborhood between groups with ($N = 19$, mean = 66.80) and without SLEV disease incidence ($N = 43$, mean = 95.05).

4. Discussion

The results of this study illustrate the influence of different landscape elements on the distribution of SLEV infections in humans. The use of satellite imagery enabled us to map the relevant ecological units that describe considerably suitable habitats for both mosquitoes and birds. The statically significant association between SLEV cases and the distance to pixels with NDVI > 0.3 revealed that it could be an important marker for SLEV risk assessment in our urban environment. The occurrence of WNV infections has also been associated with vegetation abundance (Cooke et al., 2006; Ruiz et al., 2004). Brownstein et al. (2002) revealed that vegetation abundance was significantly and positively associated with human WNV cases in the New York City area in 1999. In Córdoba city, Gleiser and Zalazar (2010) reported that mean *Culex* mosquito abundance and richness are correlated with the percentage of undeveloped and vegetated areas. In our study pixels with NDVI > 0.3 represent important vegetation patches (including canopy) immersed in urban constructions where birds rest, feed and are in contact with mosquitoes. This interaction of vectors and susceptible avian amplification hosts provides a favorable environment for amplification of SLEV. For example, in Florida after drought periods, mosquitoes are restricted to more humid habitats where birds nest, and SLEV transmission occurs due to this close encounter between them (Shaman et al., 2004). Rotela et al. (2011) constructed a decision tree model based on remotely-sensed data to generate a risk map for SLEV in Córdoba city during the 2005 outbreak. Vegetation, water bodies and satellite indexes were evaluated as factors associated to SLEV cases. They only found an inverse linear relationship between the number of SLEV cases and distance to high-vigor vegetation estimated by NDVI. In our study, we also found an association between vegetation abundance and SLEV human infections. The novel approach employed in our research is not only the use of a different analysis methodology (based on logistic regressions) and outbreak data, but also the incorporation of other variables such as distance to agriculture fields, the addition of water channels into lentic water bodies, housing density and population density that were useful to better discern the occurrence of SLEV infections.

However the LDC was not statistically significant ($p = 0.08$); the presence of LDC tends to be positively related to the occurrence of infections, while HDC has the opposite effect due to it corresponding with low values of LDC. This tendency would be supported by the significant difference in population density at the neighborhood's case–control analysis. Ruiz et al. (2004) found for WNV that a tract is more likely to include at least one case when it has lower population density among other landscape characteristics. The same pattern was observed for WNV incidence in Iowa, USA by DeGroote et al. (2008). Population density and high density housing are inversely related to vegetation. The presence of green spaces is needed for mosquito and bird habitat. Human activities not only support mosquito populations, but also provide food, nesting, and roosting habitat for both native and introduced birds (Gibbs et al., 2006). This will be important in Córdoba city since native forests have been drastically reduced in the last few years due to the advancing agricultural fields around the city, which normally include a low percentage of tree patches. A bird composition study in Córdoba city has registered 96 species of birds in different green spaces, classifying the species according to the abundance and the permanence in the city. A total of 66 species were classified as permanent residents in the city and 14 species were highly abundant. *C. picui* and *Z. auriculata* (main host proposed for SLEV in Córdoba city) were classified in both categories previously stated. In addition, the register showed that 9 species have recently colonized our urban environment (Sferco, unpublished results). Therefore, the green spaces in the city represent important habitats for bird subsistence. On the other hand, the proximity to agricultural fields was not associated to SLEV human infections in our model as it has been documented for WNV infections (DeGroote et al., 2008; Liu et al., 2008). This is due to the scarce patches of canopy available for birds nesting and resting as stated above.

The association of WNV human risk with freshwater wetlands and open water has been well documented (Cooke et al., 2006; DeGroote et al., 2008; Liu et al., 2008). Despite the fact that lotic and lentic water bodies represent favorable habitats to mosquito reproduction, these landscape elements were not associated to SLEV human infections in our model, even with the incorporation of water channels in the lentic water bodies' predictive variable. According to Reisen et al. (1992), *C. quinquefasciatus* may be found in abundance in human modified habitats such as residential areas. In Northeast Ohio, USA distance from water (lakes, ponds or streams) did not prove to be significant predictors of WNV infections (LaBeaud et al., 2008). During the 2005 SLEV outbreak in Córdoba, neither lotic nor lentic water bodies were associated to the occurrence of SLEV human cases (Rotela et al., 2011). Considering that in Córdoba city the immature stages of *C. quinquefasciatus* (main vector proposed) have been collected in diverse habitats including cisterns, tires, flowerpots, pools, ponds, riversides and water channels (Almiron and Brewer, 1996; Pires and Gleiser, 2010), it seems that large water bodies are not a limiting factor for its reproduction in urban environments.

5. Conclusions

The model highlights the areas that are more likely to experience SLEV infections. The incorporation of new predictive variables related to population density characteristics and agriculture fields have provided new valuable information and were helpful to obtain a better fit of the model. The main landscape elements contributing to the outbreak of SLEV in 2010 were the proximity to places with NDVI > 0.3 (parks, squares, riversides, other vegetated areas) and the presence of low density urban constructions, like residential areas, where population is lower for allowing the existence of more vegetation. These findings and the predictive map developed could be important and useful for public health surveillance and to improve prevention of vector–borne diseases. The predictive map may be implemented to establish campaigns aimed to decrease man-made mosquito habitats in vulnerable areas or neighborhoods. Further studies including more detail spatial analysis and new variables related to socioeconomic characteristics of population could help to better understand the SLEV infection dynamics.

Competing interest

The authors declare that they have no competing interests.

Authors' contributions

C.V.C. and E.L.E. designed the study, processed images, made GIS and statistical analysis of the data and drafted the manuscript. L.I.S., M.S.C. and W.R.A. collected the data, participated in the design, interpretation of results, coordination and drafting of manuscript. All authors revised critically the contents, read and approved the final manuscript.

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References

Almiron, W.R., Brewer, M.E., 1996. Classification of immature stage habitats of Culicidae (Diptera) collected in Cordoba, Argentina. Mem. Inst. Oswaldo Cruz. 91, 1–9.

Bradley, C.A., Gibbs, S.E., Altizer, S., 2008. Urban land use predicts West Nile virus exposure in songbirds. Ecol. Appl.: Publ. Ecol. Soc. Am. 18, 1083–1092.

Brownstein, J.S., Rosen, H., Purdy, D., Miller, J.R., Merlino, M., Mostashari, F., Fish, D., 2002. Spatial analysis of West Nile virus: rapid risk assessment of an introduced vector–borne zoonosis. Vector Borne Zoonotic Dis. (Larchmont N.Y.) 2, 157–164.

Cooke III, W.H., Grala, K., Wallis, R.C., 2006. Avian GIS models signal human risk for West Nile virus in Mississippi. Int. J. Health Geogr. 5, 36.

DeGroote, J.P., Sugumaran, R., Brend, S.M., Tucker, B.J., Bartholomay, L.C., 2008. Landscape, demographic, entomological, and climatic associations with human disease incidence of West Nile virus in the state of Iowa, USA. Int. J. Health Geogr. 7, 19.

Di Rienzo, J.A., Casanoves, F., Balzarini, M.G., Gonzalez, L., Tablada, M., Robledo, C.W., 2010. InfoStat versión 2010. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina http://www.infostat.com.ar

Diaz, A., 2009. Patrones de actividad y estacionalidad del virus St. Louis encephalitis en Córdoba, Argentina, Facultad de Ciencias Exactas, Físicas y Naturales. Universidad Nacional de Córdoba, p. 193.

Diaz, L.A., Re, V., Almiron, W.R., Farias, A., Vazquez, A., Sanchez-Seco, M.P., Aguilar, J., Spinsanti, L., Konigheim, B., Visintin, A., Garcia, J., Morales, M.A., Tenorio, A., Contigiani, M., 2006. Genotype III Saint Louis encephalitis virus outbreak, Argentina, 2005. Emerg. Infect. Dis. 12, 1752–1754.

Diuk-Wasser, M.A., Brown, H.E., Andreadis, T.G., Fish, D., 2006. Modeling the spatial distribution of mosquito vectors for West Nile virus in Connecticut, USA. Vector Borne Zoonotic Dis. (Larchmont, N.Y.) 6, 283–295.

Eastman, J.R., 2006. IDRISI Andes. Clark University, Worcester, MA.

Eisen, L., Lozano-Fuentes, S., 2009. Use of mapping and spatial and space-time modeling approaches in operational control of Aedes aegypti and dengue. PLoS Neglect. Trop. Dis. 3, e411.

ENVI RS 4.2 Software, 2004. The Environment for Visualizing Images. Research Systems, Inc., Boulder, CO, USA, Available from: http://www.ittvis.com/envi/index.asp

Estallo, E.L., Lamfri, M.A., Scavuzzo, C.M., Almeida, F.F., Introini, M.V., Zaidenberg, M., Almiron, W.R., 2008. Models for predicting Aedes aegypti larval indices based on satellite images and climatic variables. J. Am. Mosq. Control Assoc. 24, 368–376.

Estallo, E.L., Ludueña-Almeida, F.F., Visintin, A.M., Scavuzzo, C.M., Lamfri, M.A., Introini, M.V., Zaidenberg, M., Almirón, W.R., 2011. Effectiveness of normalized difference water index in modelling Aedes aegypti house index. Int. J. Remote Sens. 33, 4254–4265.

Gibbs, S.E., Wimberly, M.C., Madden, M., Masour, J., Yabsley, M.J., Stallknecht, D.E., 2006. Factors affecting the geographic distribution of West Nile virus in Georgia, USA: 2002–2004. Vector Borne Zoonotic Dis. (Larchmont, NY) 6, 73–82.

Gleiser, R.M., Zalazar, L.P., 2010. Distribution of mosquitoes in relation to urban landscape characteristics. Bull. Entomol. Res. 100, 153–158.

LaBeaud, A.D., Gorman, A.M., Koonce, J., Kippes, C., McLeod, J., Lynch, J., Gallagher, T., King, C.H., Mandalakas, A.M., 2008. Rapid GIS-based profiling of West Nile virus transmission: defining environmental factors associated with an urban-suburban outbreak in Northeast Ohio, USA. Geospatatial Health 2, 215–225.

Liu, H., Weng, Q., Gaines, D., 2008. Spatio-temporal analysis of the relationship between WNV dissemination and environmental variables in Indianapolis, USA. Int. J. Health Geogr. 7, 66.

Lopes, P., Lourenco, P., Sousa, C., Novo, T., Rodrigues, A., Almeida, P., Seixas, J., 2005. Modeling patterns of mosquito density based on remote sensing images. In: Proceedings of the II International Conference and Exhibition on Geographic Information, Estoril, Portugal.

Ozdenerol, E., Bialkowska-Jelinska, E., Taff, G.N., 2008. Locating suitable habitats for West Nile Virus-infected mosquitoes through association of environmental characteristics with infected mosquito locations: a case study in Shelby County, Tennessee. Int. J. Health Geogr. 7, 12.

Pires, D.A., Gleiser, R.M., 2010. Mosquito fauna inhabiting water bodies in the urban environment of Cordoba city, Argentina, following a St. Louis encephalitis outbreak. J. Vector Ecol.: J. Soc. Vector Ecol. 35, 401–409.

Reisen, W.K., 2003. Epidemiology of St. Louis encephalitis virus. In: Maramorosch, K., Murphy, F.A., Shatkin, A.J. (Eds.), Advances in Virus Research. Elsevier Academic Press, San Diego, pp. 139–183.

Reisen, W.K., Milby, M.M., Presser, S.B., Hardy, J.L., 1992. Ecology of mosquitoes and St. Louis encephalitis virus in the Los Angeles Basin of California, 1987–1990. J. Med. Entomol. 29, 582–598.

Rochlin, I., Turbow, D., Gomez, F., Ninivaggi, D.V., Campbell, S.R., 2011. Predictive mapping of human risk for West Nile virus (WNV) based on environmental and socioeconomic factors. PLoS ONE 6, 10.

Rotela, C.H., Spinsanti, L.I., Lamfri, M.A., Contigiani, M.S., Almiron, W.R., Scavuzzo, C.M., 2011. Mapping environmental susceptibility to Saint Louis encephalitis virus, based on a decision tree model of remotely-sensed data. Geospatial Health 6, 85–94.

Ruiz, M.O., Tedesco, C., McTighe, T.J., Austin, C., Kitron, U., 2004. Environmental and social determinants of human risk during a West Nile virus outbreak in the greater Chicago area, 2002. Int. J. Health Geogr. 3, 8.

Ruiz, M.O., Walker, E.D., Foster, E.S., Haramis, L.D., Kitron, U.D., 2007. Association of West Nile virus illness and urban landscapes in Chicago and Detroit. Int. J. Health Geogr. 6, 10.

Sabattini, M.S., Avilés, G., Monath, T.P., 1998. Historical, epidemiological and ecological aspects of arbovirus in Argentina: Flaviviridae, Bunyaviridae and Rhabdoviridae. In: Travassos da Rosa, A., Vasconcelos, P., Travassos da Rosa, J. (Eds.), An Overview of Arbovirology in Brazil and neighboring countries. Instituto Evandro Chagas, Belem, Brazil, pp. 113–134.

Shaman, J., Day, J.F., Stieglitz, M., 2004. The spatial–temporal distribution of drought, wetting, and human cases of St. Louis encephalitis in southcentral Florida. Am. J. Trop. Med. Hyg. 71, 251–261.

Spinsanti, L., Re, V., Aguilar, J., Contigiani, M., 2001. An indirect immunofluorescence assay to detect antibodies against St. Louis Encephalitis virus. Rev. Inst. Med. Trop. Sao Paulo 43, 339–340.

Spinsanti, L.I., Diaz, L.A., Glatstein, N., Arselan, S., Morales, M.A., Farias, A.A., Fabbri, C., Aguilar, J.J., Re, V., Frias, M., Almiron, W.R., Hunsperger, E., Siirin, M., Da Rosa, A.T., Tesh, R.B., Enria, D., Contigiani, M., 2008. Human outbreak of St. Louis encephalitis detected in Argentina, 2005. J. Clin. Virol.: Off. Publ. Pan Am. Soc. Clin. Virol. 42, 27–33.

Spinsanti, L.I., Re, V.E., Diaz, M.P., Contigiani, M.S., 2002. Age-related seroprevalence study for St. Louis encephalitis in a population from Cordoba, Argentina. Rev. Inst. Med. Trop. Sao Paulo 44, 59–62.

Tsai, T.F., Cobb, W.B., Bolin, R.A., Gilman, N.J., Smith, G.C., Bailey, R.E., Poland, J.D., Doran, J.J., Emerson, J.K., Lampert, K.J., 1987. Epidemiologic aspects of a St. Louis encephalitis outbreak in Mesa County, Colorado. Am. J. Epidemiol. 126, 460–473.

Vergara Cid, C., Spinsanti, L., Rivarola, M., Beltran, N., Diaz, A., Cogo, G., Maders, J., Arri, J., Chancalay, O., Contigiani, M., 2011. Detección de infecciones humanas por *Flavivirus* en la ciudad de Córdoba durante el año 2010. Rev. Argent. Microbiol. 43, 37.