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Relationship of Climatological Variables with Confirmed and Suspected Cases of the Dengue Vector

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Abstract. Dengue is endemic in Mexico, with epidemic cycles occurring approximately every three to five years, associated with the introduction of new viral serotypes into susceptible populations. This study analysed the relationship between climatological variables and dengue incidence in Morelos, Mexico, during the period 1999–2009, aiming to identify favourable conditions to inform territorially focused prevention and control measures, using spatial analysis methods. The analysis of the influence of climate on dengue transmission in Morelos demonstrated the importance of precipitation in developing early warning systems for potential epidemics. It is recommended that territorially focused preventive strategies be implemented, such as the elimination of breeding sites, fumigation, and social mobilisation in areas at risk due to environmental, social, and epidemiological factors.
Keywords: Dengue, Climatological Variables.

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1 Introduction

Dengue is a viral disease transmitted by the bite of infected mosquitoes, mainly of the Aedes genus. It is endemic in tropical and subtropical regions of Africa, Southeast Asia and America. There are an estimated 390 million infections annually, of which 96 million manifest clinically (Bhatt et al., 2013). Dengue causes a nonspecific febrile illness known as dengue fever. In a minority it leads to severe forms such as severe dengue and dengue shock syndrome, characterized by plasma extravasation, hemorrhages and hypovolemic shock, potentially fatal. The wide clinical spectrum makes effective diagnosis difficult (WHO, 2021).

There is no specific antiviral treatment. Prevention and control are mainly based on reducing the density of transmitting mosquitoes through elimination of breeding sites, fumigation and personal protection (Eisen, Beaty, Morrison & Scott, 2009). The expansion of Aedes is associated with factors such as disorderly urban growth, deficiencies in water and sanitation services, inadequate waste disposal, and limited community participation (Reiter, 2001).

Dengue is endemic in Mexico with epidemic cycles approximately every 3-5 years related to the introduction of new viral serotypes in susceptible populations (Tapia-Conyer, Méndez-Galván & Burciaga-Zúñiga, 2012). Previous research shows associations between epidemic outbreaks and climatic conditions such as temperature, precipitation and humidity that influence the reproduction of the mosquito vector and the kinetics of viral replication. However, studies are scarce at an intra-country scale considering regional climatic heterogeneities.

This work analyzed the relationship of climatological variables with the incidence of dengue in Morelos, Mexico during 1999-2009, seeking to identify favorable conditions to guide territorially focused prevention and control actions, taking advantage of spatial analysis methods.

2 Theoretical framework

Climate generators are used to estimate missing data and precipitation concentration and modified Fournier indices are calculated. The modified Fournier index characterizes the aggressiveness of precipitation and is calculated for each year, classifying it into different levels of intensity. Interpolation is applied to generate precipitation isohyets, isotherms of the maximum and minimum temperature. The inverse distance weighting (IDW) tool in ArcGis is used to perform interpolation of data from climatological stations.

The climatic data of precipitation, observed, maximum and minimum temperature are analyzed, as well as epidemiological data that are grouped by month and by epidemiological week for the period 1999-2012. A simple regression model is implemented to establish which variable could have predictive value for dengue cases. The Pearson correlation analysis method is used to determine the association between climatic variables and the spread of dengue.

Epidemiological data are obtained from the National Epidemiological Surveillance System (SINAVE), made up of all the institutions that make up the National Health System. The data are grouped by municipality, year, month, epidemiological week and number of total cases.

A simple regression model is implemented to establish which variable could have predictive value for dengue cases. The Pearson correlation analysis method is used to determine the association between climatic variables and the spread of dengue.

The climatological information system (CLICOM) has thousands of climatological stations distributed throughout the country. However, the historical database presents problems such as the integration of a considerable number of meteorological stations, the replacement and elimination of stations, as well as records without information. To complete the missing information, a methodology is implemented that includes filling information gaps using climate generators such as CLIMGEN and RClimTool. With the idea of estimating the aggressiveness of rainfall, based on the temporal variability of monthly rainfall (Oliver 1980), he proposed a rainfall concentration index (PCI), which is obtained using the following expression.

$$ICP = \frac{\sum_{i=1}^{12} p_i^2}{P^2} * 100$$

Where:

ICP Precipitation concentration index (%)

P_i Monthly precipitation (mm)

P Annual precipitation (mm)

The calculation is carried out for each year and at the end the average is obtained.

Table 1. Classification of precipitation concentration index

ICP (%)	Classification
8.3 - 10	Uniform
10 - 15	Moderately seasonal
15 - 20	Seasonal
20 – 50	Highly seasonal
50 - 100	Irregular

Arnoldus (1980) proposed a Fournier Index (IF) correction in which not only the monthly precipitation of the wettest month is considered, but also that of the rest of the months.

This modified Fournier index (MFI) characterizes the aggressiveness of precipitation and is calculated as follows:

$$IFM = \sum_{i=1}^{12} \frac{p_i^2}{P}$$

The calculation is done for each year and then the average is calculated.

Table 2. Classification of the Modified Fournier index

IFM	Classification
0 - 60	Very low
60 - 90	low
90 - 120	Moderate
120 - 160	High
160	Very high

To obtain the priority areas, it was carried out through layer arithmetic, which was obtained through some interpolations of the temperature and precipitation variables, also integrating the layer of degree of urban marginalization at the AGEB level, for geoprocessing. The layer intersection method was used.

3 Methodology

This research was carried out using the following methodology:

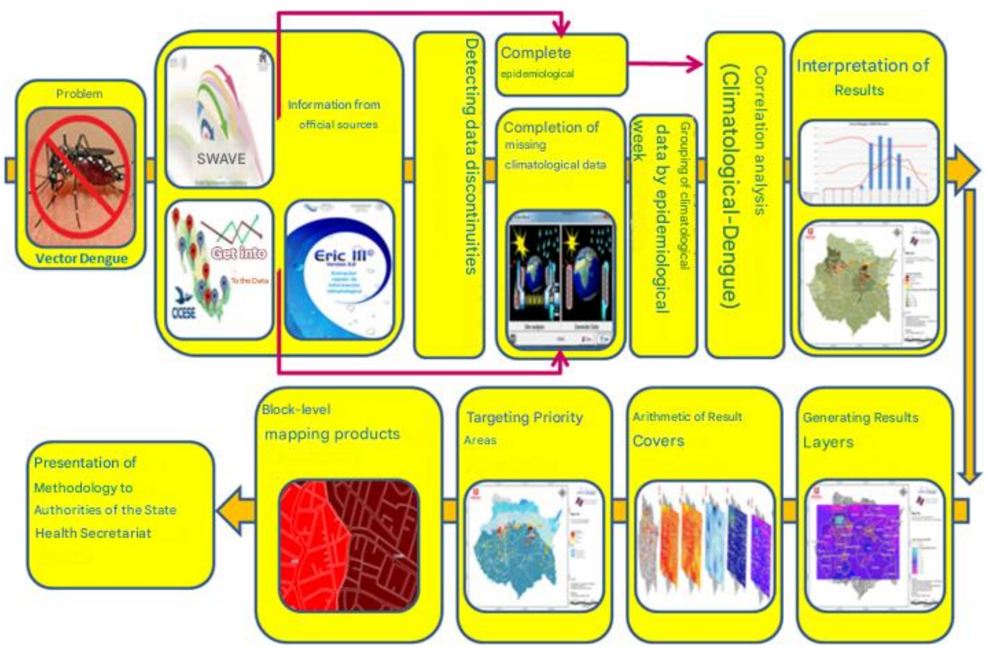


Figure 1. Diagram of applied methodology

In this work, we seek to contribute to the evaluation of the quality of climate data from the CLICOM database, using a specific methodology. The objective is to identify the correlation in the incidence rate of dengue. Through statistics from the Ministry of Health of the State of Morelos, a high number of cases is observed annually in some municipalities, attributed to the climatic and geographical conditions of the state.

Data collection was carried out in official government sites, obtaining climatological data from the National Water Commission (CONAGUA) and data on dengue cases from the Ministry of Health of the State of Morelos. The climatological data in the CLICOM database lack quality review, which can generate inconsistencies due to capture, equipment calibration or replacement. The RClimdex 1.0 application was used for quality review before filling in missing data.

In the data selection process, stations with more years of daily recording, fewer missing data, and distributed in several municipalities of the state were chosen. For dengue cases, all those provided by the Ministry of Health were selected due to their prior validation.

Data structuring involved formatting climate records according to application requirements for quality review and data completion. Completion of missing data was performed by station with the ClimGen application, requiring at least 25 years of historical data.

The validation of results was carried out to ensure the proximity of the calculated data to reality. Subsequently, the climatological data were grouped by epidemiological week and municipality to facilitate correlation with dengue cases.

Pearson's correlation analysis was applied between climatic variables and dengue cases. The results were interpreted by generating thematic maps to better describe and understand the topic of the dengue vector.

To delimit high priority areas for dengue prevention, intersection geoprocessing was carried out between the generated layers. Finally, the results were interpreted by analyzing the layer of priority areas on satellite images or Google Earth. The results will be presented to the Ministry of Health of the State of Morelos to obtain comments and suggestions on the proposed methodology, with the objective of integrating it into their planning activities in vector control.

The study was carried out in Morelos located in the Central region of Mexico, between the parallels 18° 20' and 19° 39' N and the meridians 98° 38' and 99° 30' W. It has a population of 1.9 million inhabitants distributed in 33 municipalities and a territorial area of 4,965 km2. Morelos has a warm sub-humid climate in most of the territory, with average annual temperatures of 22-26°C. Precipitation is abundant in summer with an annual average of 900-1200 mm. The dry season runs from November to May (Atlas de Riesgos del Estado de Morelos, 2012).

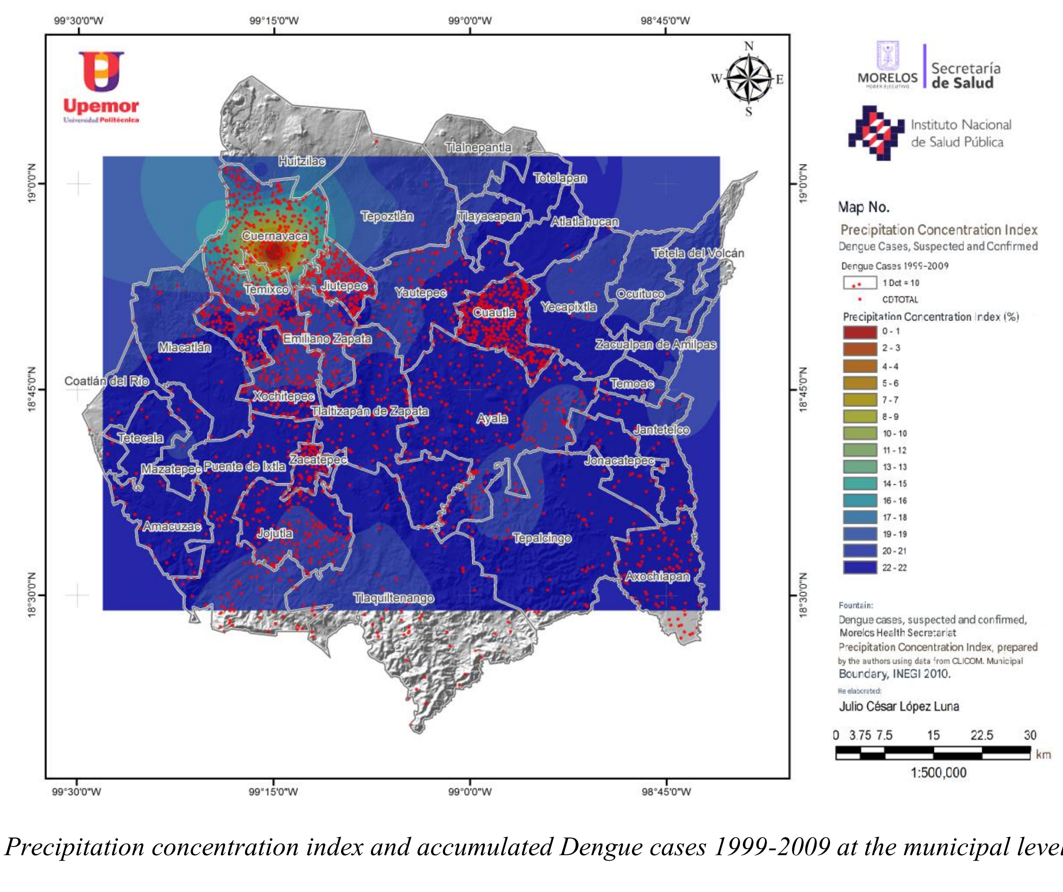


Figure 2. Precipitation concentration index and accumulated Dengue cases 1999-2009 at the municipal level

3.1. Data

Daily records of precipitation, maximum and minimum temperature from 37 weather stations in Morelos during 1999-2009 from the CLICOM database of the National Meteorological Service of Mexico were used.

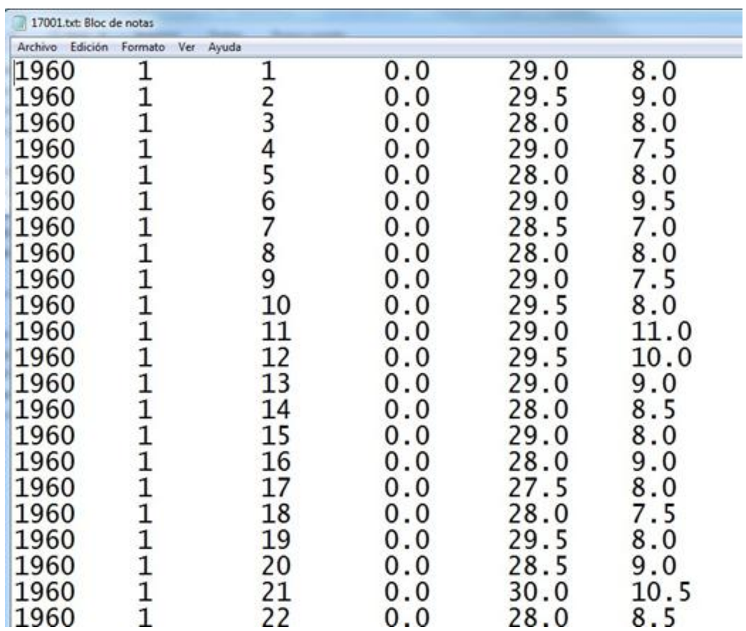
The weekly confirmed and suspected cases of dengue by municipality for the same period were provided by the National Epidemiological Surveillance System of the Morelos Health Services.

To evaluate the association between climatic variables and dengue cases, the Pearson correlation method was applied. The analyzes were performed in the R statistical platform.

Spatial distribution maps of precipitation, temperature, and dengue incidence were generated through interpolation using the Inverse Distance Weighting (IDW) method implemented in ArcGIS 10.5.

Priority areas for prevention and control actions were identified by integrating layers of climate susceptibility, social marginalization and historical cases using geoprocessing tools. The results were verified with satellite images and field inspections.

In this study, a detailed analysis of the relationship between climatic conditions and dengue cases in the state of Morelos was carried out. First, the process of obtaining and cleaning climatological data was described, as well as the collection of epidemiological data for subsequent analysis in relation to dengue cases. Climatological data were obtained using the Rapid Meteorological Information Extractor to collect daily records of maximum temperature, minimum temperature and precipitation from selected meteorological stations in Morelos and neighboring states. The data was then cleaned to remove station-specific headers and information, resulting in an integrated text file con la siguiente estructura para cada estación seleccionada: año, mes, día, precipitación, temperatura máxima y temperatura mínima.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1960	1	1	0.0	29.0	8.0
1960	1	2	0.0	29.5	9.0
1960	1	3	0.0	28.0	8.0
1960	1	4	0.0	29.0	7.5
1960	1	5	0.0	28.0	8.0
1960	1	6	0.0	29.0	9.5
1960	1	7	0.0	28.5	7.0
1960	1	8	0.0	28.0	8.0
1960	1	9	0.0	29.0	7.5
1960	1	10	0.0	29.5	8.0
1960	1	11	0.0	29.0	11.0
1960	1	12	0.0	29.5	10.0
1960	1	13	0.0	29.0	9.0
1960	1	14	0.0	28.0	8.5
1960	1	15	0.0	29.0	8.0
1960	1	16	0.0	28.0	9.0
1960	1	17	0.0	27.5	8.0
1960	1	18	0.0	28.0	7.5
1960	1	19	0.0	29.5	8.0
1960	1	20	0.0	28.5	9.0
1960	1	21	0.0	30.0	10.5
1960	1	22	0.0	28.0	8.5

Figure 3. file with .dat extensión

The climatological data were then analyzed and mapped. For example, the Modified Fournier Index map showed that 92.4% of the study area had an annual average water depth greater than 160 mm, with 5.8% between 120 mm and 160 mm. Additionally, the maximum temperature map indicated that 68% of the study area experienced temperatures between 25° and 30°, with the majority between 25° - 26° and 29° - 30°.

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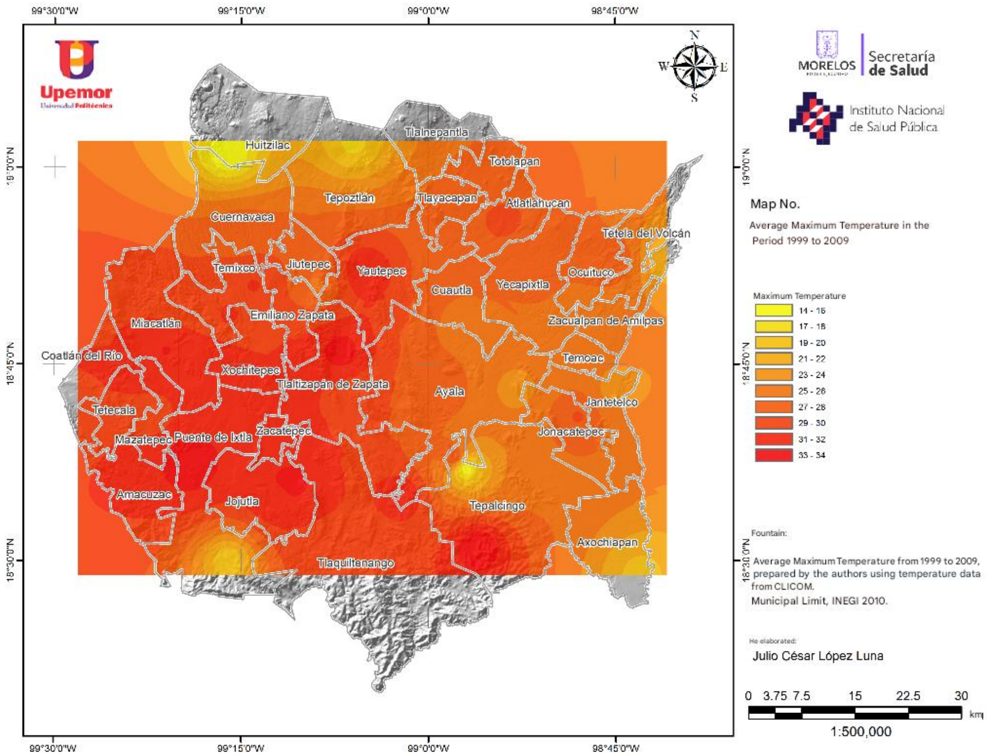

Figure 4. Map of average maximum temperature in the period 1999 to 2009 of the study área

Then, the correlation between climatological variables and dengue cases was analyzed. Missing data were generated, the data were grouped by epidemiological week and the correlation of climatological variables and dengue cases was carried out. In addition, maps of climatological variables were generated to better visualize the distribution of dengue cases in relation to climatic conditions. A moderate positive correlation between precipitation and dengue cases, significant positive correlation between normal precipitation and dengue cases was shown, with a correlation coefficient of 0.5844 and an R-squared value of 0.3364.

Climatological variables	Correlation with suspected and confirmed Dengue cases
Temp. Maximum Average (completed)	-0.08
Temp. Maximum Average (Original Base Eric III)	0.04
Temp. Maximum Average (Original CONAGUUA Base)	0.04
Temp. Minimum Average (completed)	0.10
Temp. Minimum Average (Eric III original base)	0.10
Temp. Minimum Average (Original CONAGUA Base)	0.11
Precipitation (completed)	0.58
Precipitation (Eric III Original Base)	0.69
Precipitation (original CONAGUA base)	0.69

Figura 1 Resultados en R de matriz de correlación de Pearson

The results in the normal precipitation correlation test were, t=24.032, df =1113 and $p < 2.2e-16$, the alternative hypothesis: the true correlation is not equal to 0, for the 95% confidence interval: 0.5444604 0.6218552, r= 0.5844857 and r^2= 0.3364.

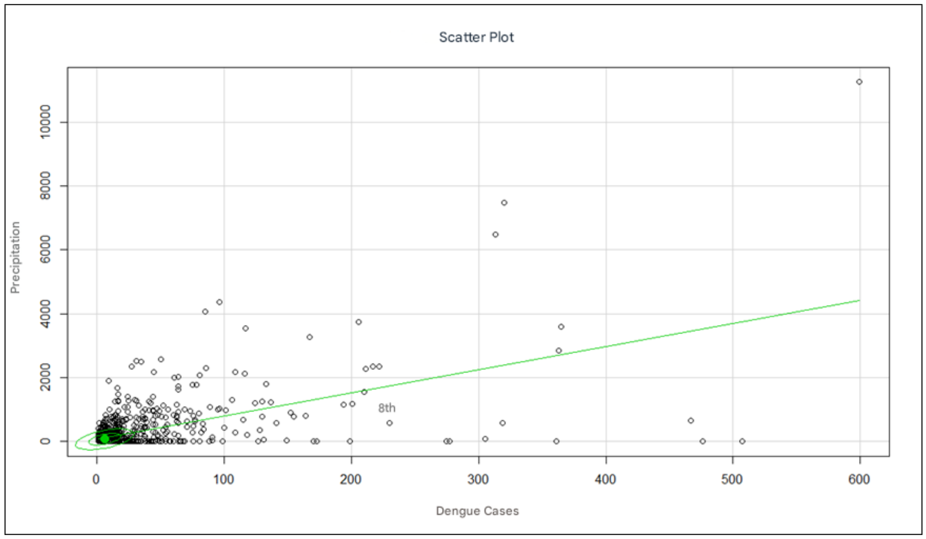

Figure 6. Precipitation scatter plot

This means that rainy conditions favored the reproduction of the dengue vector, which influenced the increase in cases. In addition, priority areas for dengue prevention were identified, which is crucial to implement effective vector-borne disease control strategies.

3.2. Results

Weekly accumulated precipitation showed a moderate positive correlation ($r=0.58$, $p<0.001$) with reported dengue cases, explaining 34% of the variability during 1999-2009.

PEARSON CORRELATION	Cases Dengue 1999	Cases Dengue 2002	Cases Dengue 2003	Cases Dengue 2004	Cases Dengue 2005	Cases Dengue 2006	Cases Dengue 2007	Dengue Cases 2008	Dengue Cases 2009
Tmax Prom.	0.32	-0.14	-0.20	-0.23	0.29	0.06	-0.30	-0.12	0.12
Tmin Avg.	0.17	0.05	0.02	0.19	0.31	0.05	0.15	0.23	0.01
Precipitation	0.47	0.43	0.17	0.49	0.22	0.41	0.52	0.62	0.21
Precipitation with 4 weeks lag	0.25	0.50	0.26	0.57	0.19	0.46	0.54	0.62	0.22

Figure 7. Pearson correlation results by year.

The average weekly maximum temperature had a very weak negative correlation (r=-0.08, p<0.001). The average weekly minimum temperature had a very low positive correlation (r=0.10, p<0.001).

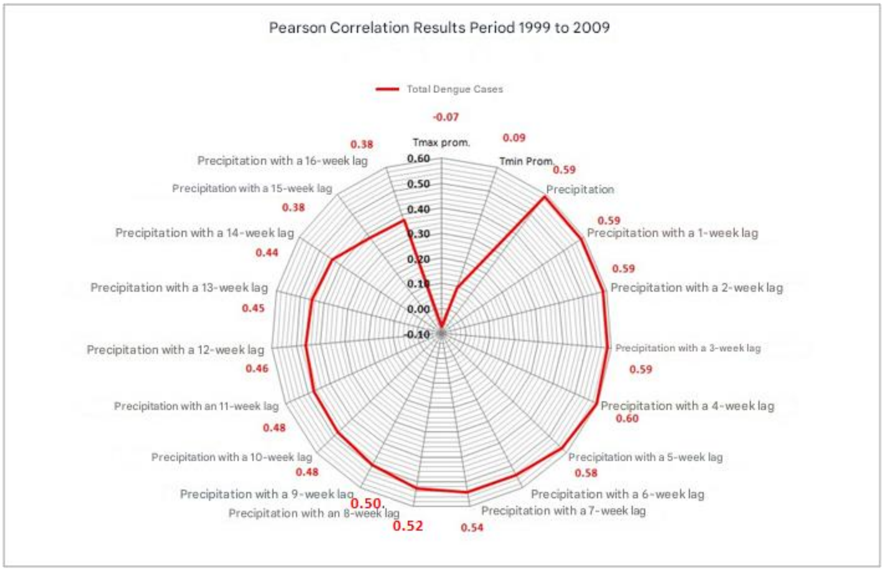

Figure 8. Pearson correlation results for the period 1999 to 2009

Precipitation maps show a seasonal pattern concentrated in summer. The Fournier index classified an annual thickness greater than 160 mm in 92% of the territory. The municipalities with the highest cumulative incidence were located in areas with rainfall of 160-220 mm, consistent with the association found. The average maximum temperatures between 25-30oC and minimum temperatures of 8-12oC coincided spatially with municipalities with high historical dengue transmission. The highest priority areas for focused preventive actions, determined by integrating climatic, social and epidemiological factors, were located mainly in the south and southeast of Morelos.

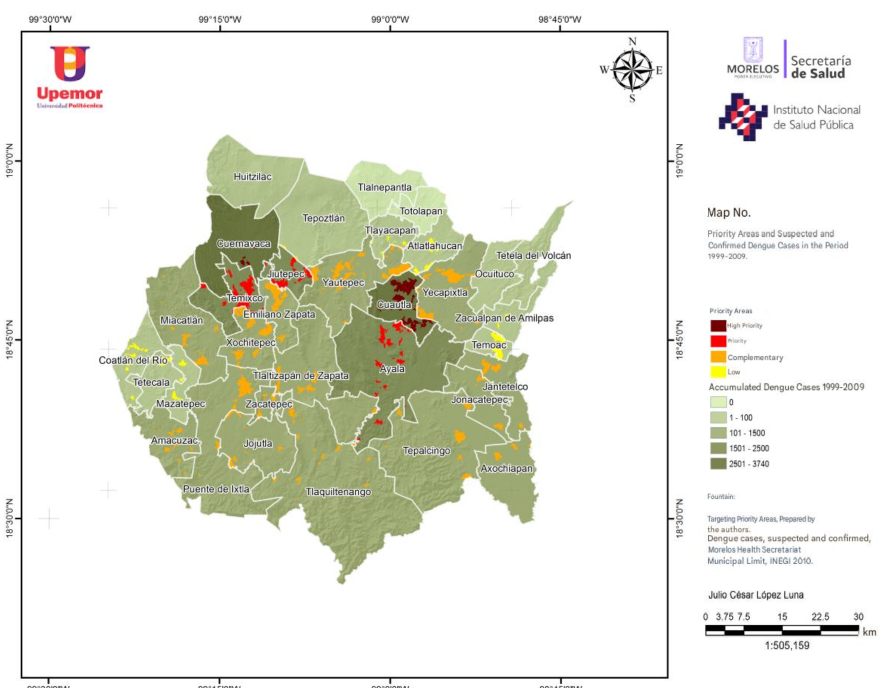

Figure 9. Priority areas and accumulated Dengue cases 1999-2009 at the municipal level

The analysis with high spatial resolution satellite images and field visits corroborated conditions conducive to the transmission of dengue in these territories.

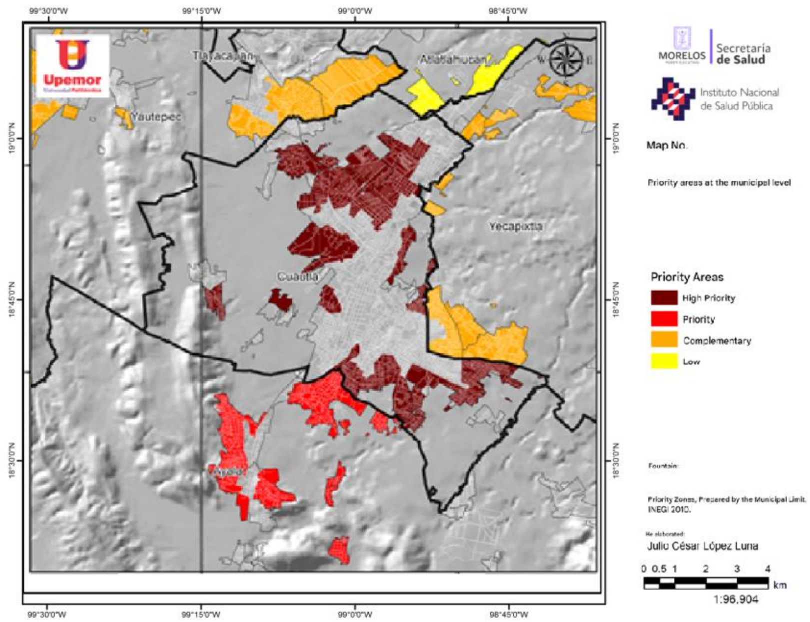

Figure 10 Results at the municipal disaggregation level.

3.3. Discussion

Precipitation exhibited a significant association with the anal incidence of dengue, consistent with previous reports [6,9]. Rains increase the availability of natural and artificial breeding sites for the vector Aedes aegypti (Barrera, 2015). Temperature showed a weak correlation possibly due to non-linear effects on mosquito ecology and viral replication kinetics (Mordecai et al., 2017). The optimal range is estimated between 25-30°C. The mapping of cases, precipitation and temperature facilitated the identification of spatial patterns linked to intra-state climate heterogeneity.

The integration of multiple layers through geoprocessing in GIS made it possible to delimit priority territories to focus prevention and control interventions, taking advantage of the municipal resolution of the data. Precipitation was an epidemiologically relevant predictor. A precipitation anomaly monitoring system could provide early warning of seasonal increases in transmission risk. Temperature demonstrated limited utility for surveillance in this context. However, climate change projections indicate that warming would prolong transmission throughout the year, expanding the geographic range of viable Aedes densities (Colón-González et al., 2018).

4 Conclusions

The analysis of the influence of climate on dengue transmission in Morelos showed the value of precipitation to develop early warning systems against possible epidemics.
It is recommended to implement territorially focused preventive strategies such as elimination of breeding sites, fumigation and social mobilization in risk areas due to environmental, social and epidemiological factors.

Mapping of cases, climate and population through spatial analysis in GIS proved to be an effective tool for strategic planning, surveillance, prevention and localized control of dengue.

References

Barrera, R. (2015). Impact of climatic variability and future climate change on dengue. In R. Akhtar (Ed.), *Climate change and insect pests* (pp. 193–202). CABI. https://doi.org/10.1079/9781780643786.0193

Bhatt, S., Gething, P. W., Brady, O. J., *et al.* (2013). The global distribution and burden of dengue. *Nature, 496*(7446), 504–507. https://doi.org/10.1038/nature12060

Colón-González, F. J., Harris, I., Osborn, T. J., *et al.* (2018). Limiting global-mean temperature increase to 1.5–2 °C could reduce the incidence and spatial spread of dengue fever in Latin America. *Proceedings of the National Academy of Sciences of the United States of America, 115*(24), 6243–6248. https://doi.org/10.1073/pnas.1718945115

Colón-González, F. J., Lake, I. R., & Bentham, G. (2011). Climate variability and dengue fever in warm and humid Mexico. *American Journal of Tropical Medicine and Hygiene, 84*(5), 757–763. https://doi.org/10.4269/ajtmh.2011.10-0609

Earnest, A., Tan, S. B., & Wilder-Smith, A. (2012). Meteorological factors and El Niño Southern Oscillation are independently associated with dengue infections. *Epidemiology & Infection, 140*(7), 1244–1251. https://doi.org/10.1017/S095026881100183X

Eisen, L., Beaty, B. J., Morrison, A. C., & Scott, T. W. (2009). Proactive vector control strategies and improved monitoring and evaluation practices for dengue prevention. *Journal of Medical Entomology, 46*(6), 1245–1255. https://doi.org/10.1603/033.046.0601

Gobierno del Estado de Morelos. (2012). *Atlas de riesgos del Estado de Morelos.* GEM.

Hurtado-Díaz, M., Riojas-Rodríguez, H., Rothenberg, S. J., Gomez-Dantés, H., & Cifuentes, E. (2007). Impact of climate variability on the incidence of dengue in Mexico. *Tropical Medicine & International Health, 12*(11), 1327–1337. https://doi.org/10.1111/j.1365-3156.2007.01930.x

Mordecai, E. A., Cohen, J. M., Evans, M. V., *et al.* (2017). Detecting the impact of temperature on transmission of Zika, dengue, and chikungunya using mechanistic models. *PLoS Neglected Tropical Diseases, 11*(4), e0005568. https://doi.org/10.1371/journal.pntd.0005568

Reiter, P. (2001). Climate change and mosquito-borne disease. *Environmental Health Perspectives, 109*(Suppl 1), 141–161. https://doi.org/10.1289/ehp.01109s1141

Tapia-Conyer, R., Méndez-Galván, J. F., & Burciaga-Zúñiga, P. (2012). Dengue in Mexico: An urgent priority. *Salud Pública de México, 54*(6), 525–526. https://doi.org/10.1590/S0036-36342012000600001

World Health Organization. (2021). *Dengue and severe dengue.* https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue