Journal of Infection and Public Health (2017) 10, 446—456

ELSEVIER

Journal of Infection and Public Health

http://www.elsevier.com/locate/jiph

Estimating and mapping the incidence of dengue and chikungunya in Honduras during 2015 using Geographic Information Systems (GIS)

Lysien I. Zambrano[a,b], Manuel Sierra[c,d], Bredy Lara[e], Iván Rodríguez-Núñez[f], Marco T. Medina[g], Carlos O. Lozada-Riascos[h], Alfonso J. Rodríguez-Morales[i,j,k,l,*]

[a] *Department of Morphological Sciences, School of Medical, Sciences, Universidad Nacional Autónoma de Honduras, Tegucigalpa, Honduras*
[b] *Cardiovascular Division, Department of Physiology, Escola Paulista de Medicina (UNIFESP-EPM), Universidade Federal de São Paulo, São Paulo, Brazil*
[c] *Information Management Unit, Hospital Escuela Universitario (HEU), Tegucigalpa, Honduras*
[d] *Department of Public Health, School of Medical Sciences, Universidad Nacional Autónoma de Honduras, Tegucigalpa, Honduras*
[e] *Health Surveillance Unit, Ministry of Public Health of Honduras (SESAL), Tegucigalpa, Honduras*
[f] *Escuela de Kinesiología, Facultad de Ciencias de la Salud, Universidad San Sebastián, Concepción, Chile*
[g] *Deanship, School of Medical Sciences, Universidad Nacional Autónoma de Honduras, Tegucigalpa, Honduras*
[h] *Regional Information System, Universidad Tecnológica de Pereira (UTP), Pereira, Risaralda, Colombia*
[i] *Research Group Public Health and Infection, Faculty of Health Sciences, Universidad Tecnológica de Pereira (UTP), Pereira, Risaralda, Colombia*
[j] *Committee on Zoonoses and Hemorrhagic Fevers of the Colombian Association of Infectious Diseases (Asociación Colombiana de Infectología, ACIN), Bogotá, Colombia*

* Corresponding author at: Universidad Tecnológica de Pereira, Facultad de Ciencias de la Salud, Departamento de Medicina Comunitaria, Piso 3, La Julita, Pereira, Risaralda, Colombia.
E-mail addresses: arodriguezm@utp.edu.co, ajrodriguezmmd@gmail.com (A.J. Rodríguez-Morales).

http://dx.doi.org/10.1016/j.jiph.2016.08.003
1876-0341/

[k] *Working Group on Zoonoses, International Society for Chemotherapy, Aberdeen, United Kingdom*
[l] *Organización Latinoamericana para el Fomento de la Investigación en Salud (OLFIS), Bucaramanga, Santander, Colombia*

Received 8 March 2010; received in revised from 23 September 2010; accepted 24 September 2010

KEYWORDS
Dengue;
Chikungunya;
Arboviruses;
Infectious diseases epidemiology;
Honduras

Summary: Geographical information systems (GIS) use for development of epidemiological maps in dengue has been extensively used, however not in other emerging arboviral diseases, nor in Central America. Surveillance cases data (2015) were used to estimate annual incidence rates of dengue and chikungunya (cases/100,000 pop) to develop the first maps in the departments and municipalities of Honduras. The GIS software used was Kosmo Desktop 3.0RC1®. Four thematic maps were developed according departments, municipalities, diseases incidence rates. A total of 19,289 cases of dengue and 85,386 of chikungunya were reported (median, 726 cases/week for dengue and 1460 for chikungunya). Highest peaks were observed at weeks 25th and 27th, respectively. There was association between progression by weeks ($p < 0.0001$). The cumulated crude national rate was estimated in 224.9 cases/100,000 pop for dengue and 995.6 for chikungunya. The incidence rates ratio between chikungunya and dengue is 4.42 (ranging in municipalities from 0.0 up to 893.0 [San Vicente Centenario]). Burden of both arboviral diseases is concentrated in capital Central District (>37%, both). Use of GIS-based epidemiological maps allow to guide decisions-taking for prevention and control of diseases that still represents significant issues in the region and the country, but also in emerging conditions.

Introduction

Arboviral diseases, such as dengue and chikungunya [1,2], and now Zika [3], represent a public health problem especially in tropical countries, including those in Latin America, such as Honduras [4]. However, due to tourism and migration, also in non-endemic areas, as has been reported [5,6]. Whilst the epidemiology of dengue and chikungunya is well known in many countries, including its social and climatic factors associated, few data and reports are available from Central American countries, particularly from Honduras [1,4,7,8]. Previous studies in this country have addressed basic analyses of the epidemiological characteristics of epidemics since 1978 [9], up to the assessment of the impact of climate variability and change on dengue in 2010 [4]. Nevertheless, since ending 2014, but particularly 2015, dengue is not the only arboviral disease of epidemiological importance in Honduras and Central America, chikungunya arrived to the country and become endemic quickly as in other countries of Latin America [2,10]. In 2016, also Zika epidemics begun to be of concern [11].

In the case of chikungunya, there are not yet studies from Honduras, and there are very few from Central America [10,12], indicating its importance as well analyzing in detail its epidemiological implications. A disease, different to dengue, that would progress to a chronic phase [13], producing particularly the chronic inflammatory rheumatism in around half of patients, according to recent estimates and measurements in Latin America [14—16]. This is leading to a significant burden of disease (in disability and costs) [17], has been estimated in the region and in detail in some countries such as Colombia, in addition to the well-known burden of dengue [17—20]. Even more, coinfections between dengue and chikungunya can occur and have been reported [21—24].

As part of enhanced efforts in control and risk assessment for dengue and chikungunya in Latin America (as well for other arboviral and tropical diseases), the Regional Information System of the Coffee-Triangle Region, together with the Universidad Tecnologica de Pereira (through the Public Health and Infection Research Group), the Ministry of Health of Honduras and the Universidad Nacional Autónoma de Honduras, among other international institutions, are working together in the academic analysis of epidemiological information of infectious diseases in regional and national scales [16], including diseases such as dengue and chikungunya [4,17,19,25—27]. In this setting, this study was aimed to estimate incidence rates of dengue and chikungunya in 2015 for Honduras and its departments and to develop GIS-based epidemiological maps for these arboviral diseases in the country.

Methods

Honduras is a Central American country constituted by 18 departments (main administrative level) (Fig. 2) and 298 municipalities (second administrative level) (Figs. 3 and 4). The Honduran territory presents climatic, geographic and epidemiological conditions suitable for transmission of multiple infectious diseases, particularly vector-borne diseases. *Aedes aegypti*, vector of both, dengue and chikungunya, is widely distributed all over the territories [28]. As other tropical countries, compromise large areas where environmental factors such as temperature, humidity, precipitation, latitude and altitude, as well as social, cultural, economic and political factors are suitable for sustained transmission. Whilst this disease is under surveillance; prevention and control programs are still ineffective, even more in the case of chikungunya that still deserves more research and study in this country as well in Latin America. In this setting, is of utmost importance to assess surveillance health information systems that would allow estimations of its morbidity in the whole country.

For this observational, retrospective and cross-sectional study, the epidemiological data were collected from national surveillance system, obtaining the number of cases for each department and each municipality of the country by year 2015 (detailed by weeks). Data used for this study are constituted from confirmed cases, which have been revised in terms of data quality. Data proceed for this study from 298 primary municipal notification units, collected at the 18 department notification units, later consolidated and centralized in Tegucigalpa (Capital District, CD). Cases of dengue and chikungunya have been clinically and laboratory confirmed (by serology and RT-PCR).

Using official reference population data (National Institute of Statistics, INE), estimates of the annual incidence rates for all the departments and municipalities of the country during the study period were calculated (cases/100,000 pop) to provide estimates of the dengue and chikungunya incidence in the country and by department and municipalities. Main incidence rates were estimated including their 95% confidence intervals (95%CI). Linear regression models between dengue and chikungunya cases per week in order to explore associations were also performed, with a 95% of confidence, p significant <0.05. Statistical analyses were performed with Excel 365® for Windows 8®, InfoStat® and PSPP®.

In addition, national GIS-based maps, by departments and municipalities with the distribution of dengue and chikungunya, were generated. The software Microsoft Access® was the platform to design the spatial databases used, to import incidence rates by departments, municipalities and disease, to the GIS software. The Client GIS software Open source used was Kosmo Desktop 3.0 RC1®. The shapefiles of departments (.shp) were linked to data table database through spatial join operation, in order to produce digital maps of annual incidence rates by departments and municipalities.

Results

During the study period, a total of 19,289 cases of dengue and 85,386 of chikungunya were reported in Honduras, with a median of 726 cases/week for dengue (ranging from 291 to 1789) and of 1460 for chikungunya (ranging 387—4175) (Figs. 1—5). Highest peak of cases of dengue was reached during epidemiological week 25th, whilst for chikungunya was at the 27th (Fig. 1). There was an association between the increase and decrease by weeks across the year between both diseases, which was evidenced at a linear regression model for dengue and chikungunya ($r^2 = 0.6741$; $F = 103.4$; $p < 0.0001$) (Fig. 1).

The cumulated crude national rate was estimated in 224.9 cases/100,000 pop for dengue (95%CI 222.0—228.0) and 995.6 for chikungunya (95%CI 989.0—1002.0). The national incidence rates ratio between chikungunya and dengue was 4.42 (ranging in departments from 0.032 [Gracias a Dios] up to 78.44 [Francisco Morazán]; and in municipalities from 0.0 up to 893.0 [San Vicente Centenario]) (Fig. 3).

From the total of dengue, 12.35% of cases were from Choluteca, the southernmost department of the country (531.9 cases/100,000 pop) (Fig. 2), followed by Comayagua with 11.84% (445.9), the capital department (Fig. 2). Nevertheless, Valle presented the highest incidence rate (634.5 cases/100,000 pop) (Fig. 2). From the total of chikungunya, 38.4% of cases were from Francisco Morazán (2110.8 cases/100,000 pop) (Fig. 2), followed by Cortes with 23.2% (1221.6), Yoro with

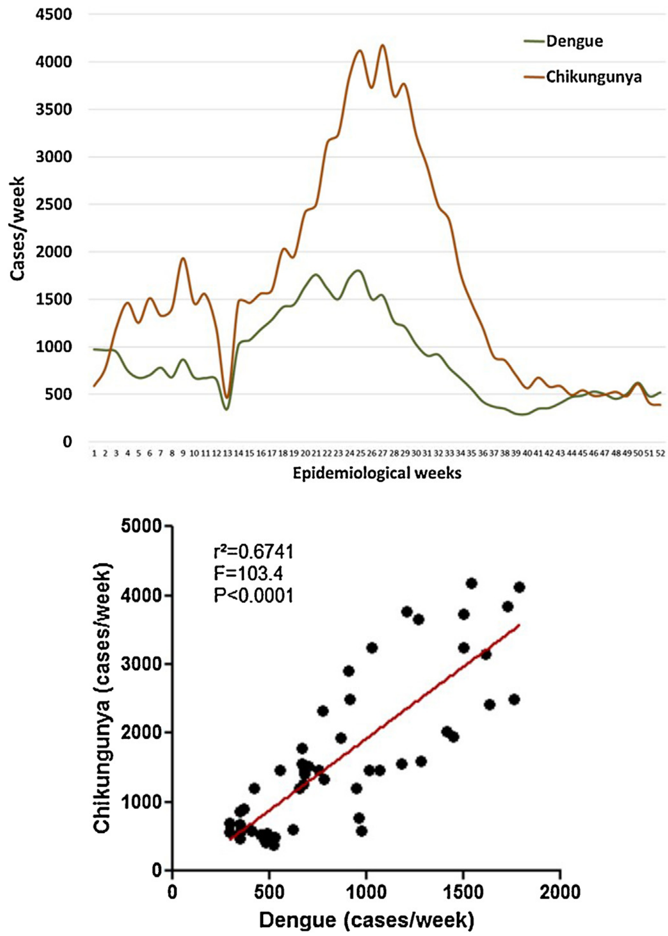

Figure 1 Temporal distribution by epidemiological weeks of number of cases of dengue and chikungunya in Honduras, 2015, and its relation in a linear regression model.

7.15% (1039.4) and Olancho with 6.74% (1070.3), these four departments concentrated more than 75% of the cases of the country (Fig. 2).

Cases of both diseases were reported in all the departments of the country (even insular areas, such as Islas de la Bahía, Bay Islands) (Fig. 2). There were departments with simultaneous high incidence of both diseases, such as Olancho and Yoro (>250 cases/100,000 pop of dengue and >1000 of chikungunya) (Fig. 1); departments with high incidence of dengue (>250) but low of chikungunya (<1000) such as Valle, Choluteca, Comayagua, among others (Fig. 2); departments with high incidence of chikungunya (>1000) but low of dengue (<250) such as Francisco Morazán and Cortés (Fig. 2); and those with relative low incidence of both diseases when compared with the other groups of departments (<250 for dengue and <1000 for chikungunya), such as Colón, Ocotepeque, Lempira, Intibucá and Gracias a Dios (Fig. 2).

GIS-based maps show that dengue incidence is higher in southern departments whilst in the case of chikungunya is more north-central departments. In any case, all the departments of Honduras are affected by both diseases (Fig. 2).

At municipalities level, Valle the department with highest incidence of dengue has the municipality with highest dengue incidence in the whole country, 1951.6 cases/100,000 pop (1.95%, ~2 cases per 100 persons) (Fig. 3), followed by the Central District (Capital) in Francisco Morazán department (1922 cases/100,000 pop) (the District reported 51.02% of the cases of the country), La Paz municipalitiy (La Paz department) (1482.8), Juticalpa (Olancho) (1393.6), Comayagua (Comayagua) (1136.5), Amapala (Valle) (1114.3), Santa Rosa de Copán (Copán) (1112.3) and San José de Colinas (Santa Bárbara) (1109.1) (Fig. 3). These 8 departments concentrated 64.69% of the dengue cases of Honduras. From the total number of municipalities, there were only 60 (out of 298, 20.1%) that did not report any cases of dengue during 2015.

In the case of chikungunya, at Santa Bárbara department were located the municipalities

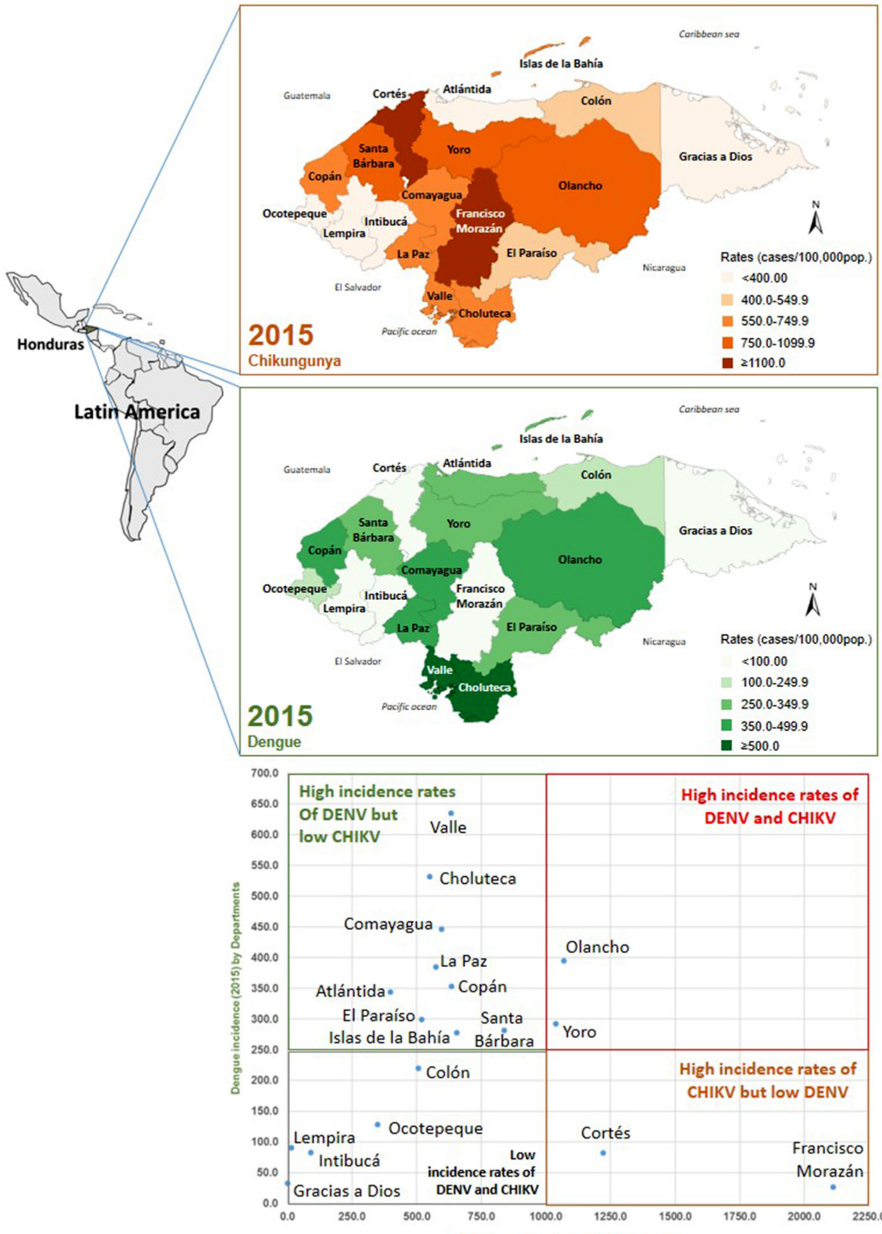

Figure 2 Geographic distribution by GIS-based map of the estimated incidence rates for dengue and chikungunya in Honduras, 2015 by departments. These maps were made with the support in a Geographic information system (Kosmo—GIS).

with highest incidence rates, San Vicente Centenario with 24,312.6 cases/100,000 pop (24.31%, ~1 case per 4 persons) and Santa Rita with 5,218.5 cases/100,000 pop (5.22%, ~5 cases per 100 persons) (Fig. 4). These were followed by Caridad (4822.5) and Aramecina (4050.4) in Valle department, San Juan (La Paz) (3787.9), San Francisco de Ojuera (Santa Bárbara) (3197.0), Santa Rosa Copán (3117.7), Juticalpa (3017.5), San Antonio de Flores (Choluteca) (2896.4) and the Central District (2676.4) (this report 37.31% of the country chikungunya cases) (Fig. 4). These 10 municipalities concentrated 46.64% of the cases. From the total number of municipalities, there were only 36 (out of 298, 12.1%) that did not report any cases of chikungunya during 2015.

Central District, Santa Rosa de Copán and Juticalpa reported a high number of cases and a high incidence rate of both arboviral diseases (Figs. 3 and 4). Highest peak of cases of dengue at the Central District was reached during epidemiological week 21th, whilst for chikungunya was at

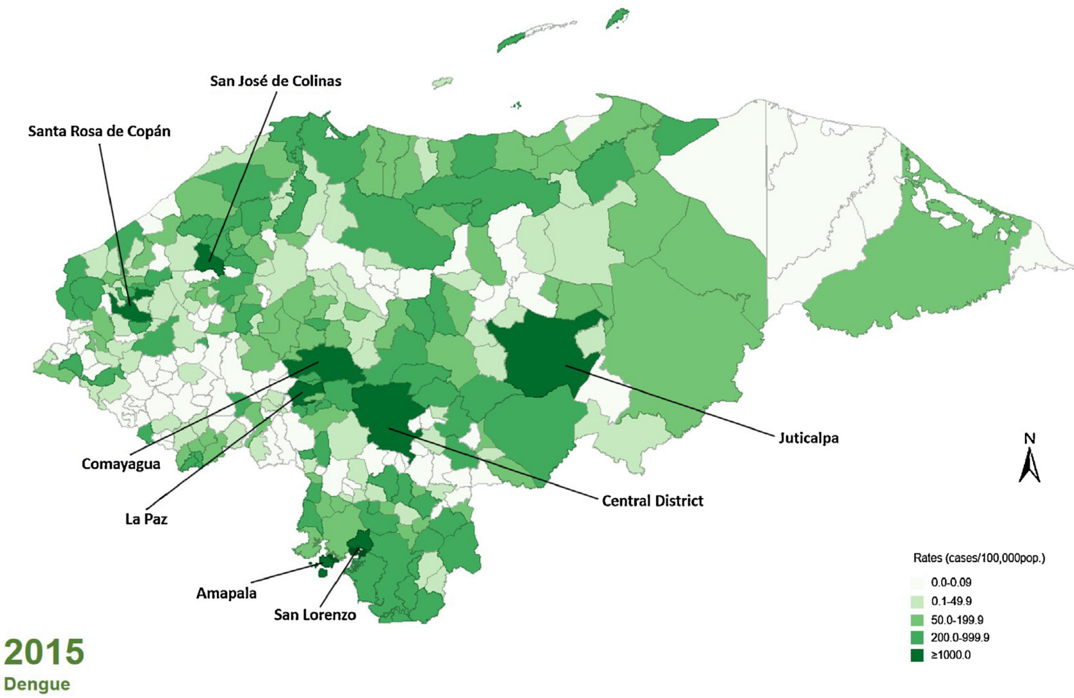

Figure 3 Geographic distribution by GIS-based map of the estimated incidence rates for dengue in Honduras, 2015 by municipalities. These maps were made with the support in a Geographic information system (Kosmo—GIS).

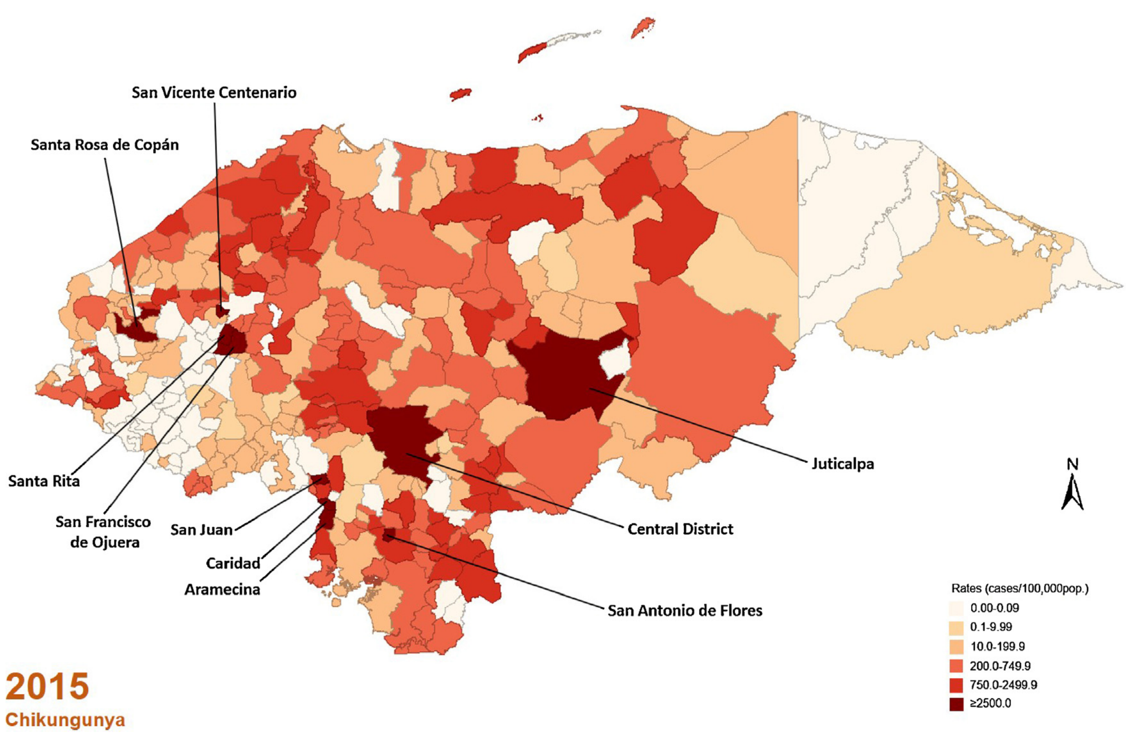

Figure 4 Geographic distribution by GIS-based map of the estimated incidence rates for chikungunya in Honduras, 2015 by municipalities. These maps were made with the support in a Geographic information system (Kosmo—GIS).

the 25th (Fig. 5), as occurred at national level, there was also a clear relationship or association between the increase and decrease of cases by weeks across the year in the Central District, which

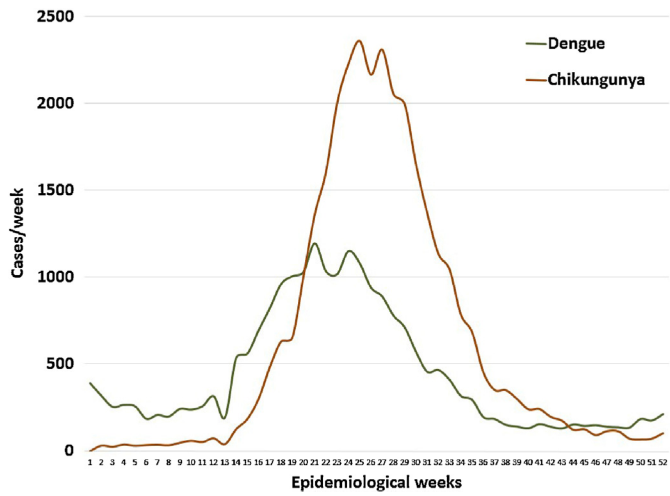

Figure 5 Temporal distribution by epidemiological weeks of number of cases of dengue and chikungunya in the Central District, Honduras, 2015.

was evidenced at a linear regression model between dengue and chikungunya ($r^2 = 0.6130$; $F = 79.21$; $p < 0.0001$).

Discussion

During last decade, but particularly in the last two years, arboviral diseases (such as dengue, chikungunya and Zika) have increased globally its importance, especially in Latin America [10,17,29]. This region has recently observed the arrival of chikungunya and Zika [3], diseases with multiple epidemiological and clinical implications still to be fully assessed and described [30].

Up to February 19, 2016, a cumulate of 7,328,012 cases (2013—2016) have been reported of dengue in the Americas according the Pan American Health Organization, 131,302 in Honduras. For chikungunya, 1,890,772 cases (2013—2016) have been reported, 94,074 in Honduras. For Zika these figures are up to the same date, 130,689 cases for the Americas and 4592 for Honduras. That means that up to 9,349,473 people have been notified with one of these arboviral diseases in the Americas [31], 229,968 in Honduras. Previous studies have estimated not just the acute impact of chikungunya in the region and in Honduras, but also the number of possible chronic cases (post-chikungunya chronic inflammatory rheumatism, pCHIK-CIR), in a range between 385,835 and 429,058 cases just for 2014 (between 1842 and 2048 in Honduras) [13], nevertheless no specific studies have directly measured this complication in a cohort of patients in the country, nor is under surveillance. Although this, also estimations of the burden in terms of disability have been also estimated for the region and the country, in a range of 25.45—28.31 DALYS (disability-adjusted life years) per 100,000 pop in the Americas and between 8.9 and 9.9 in Honduras [18].

In this changing setting, public health tools for detailed analyses, such as the use of GIS-epidemiological maps [32], are of high relevance for any affected country. In the case of Central American territories, there is a clear lack of studies developing such maps for infectious diseases, even more for dengue and chikungunya. None previously study about it was published in Honduras, which has been particularly affected from dengue since many decades ago, and would be in the future also as part of the climate change and variability and socioeconomical conditions as has been previously evidenced [4,9]. Now affected by chikungunya and also beginning to be affected by Zika.

In this study, we estimated the incidence rates of both diseases, dengue and chikungunya, and generated epidemiological maps for them in two geographical levels (departments and municipalities). Although chikungunya incidence was higher than dengue (as much as 800× in one municipality), the last one is still important in the country, also more associated fatal outcomes. Chikungunya appears to followed the patterns of dengue in the country (existing there for decades), then, as we did, integral epidemiological study of both arboviral diseases is essential from now and go on. Although, as has been stated, this may not provide all the answers, particularly from the clinical point of view is particularly useful for public health evidenced-based decisions [33]. Developed maps, would provide a baseline epidemiological information for multiple assessment of the differentiated risk related of acquire such diseases in certain areas (departments and municipalities) of Honduras, as has been proposed particularly for dengue [34—36]. In the case of chikungunya, there have been a lack GIS-based publications during the ongoing epidemics in Latin America, with the exception of Colombia [17,19,26,27].

Use of GIS-based epidemiological maps allow to integrate preventive and control strategies, as well public health policies, for joint control of these vector-borne diseases in Honduras [27], which also should be followed by other countries in Central America. Even more with the recent arrival of Zika (up to July 14, 2016, there have been 26,276 suspected cases reported in Honduras [46 confirmed by laboratory]), these tools are also important to be developed. GIS-based maps for Zika, integrated to the current dengue and chikungunya maps, will be nearly developed in Honduras. In the meantime, if Zika follow the path of dengue and chikungunya, those areas with high incidence rates of these, would be also of high risk for this new arboviral disease.

As dengue, chikungunya and Zika are transmitted primarily by *Aedes aegypti*, maps of these infections as well for coinfections will be also needed [23,24,26,27]. In areas where these arboviruses are simultaneously cocirculating, combined infections can occur and deserve more study [21,31] In addition to the public health implications, use of these maps would also provide relevant information in order to assess the risk of travelers with specific destinations in highly transmission areas with the idea of giving prevention advice [26,27,37], even more because they play also an important role in the virus spread, as occurs with the arrival of chikungunya and Zika from other countries (imported cases) to Honduras and other countries in Latin America. For example, the department of Islas de la Bahía (Bay Islands), including Roatan, is a highly visible and visited destination among tourists during all seasons, with a considerable occurrence of dengue and chikungunya, as showed herein, 655.2 cases/100,000 pop for the first and 277.6 for the second, but being higher in Utila islands (1009.6 and 48.1, respectively), followed by Roatan islands (799.4 and 329.2, respectively), then highlighting the need for increased prevention of national and international travelers visiting this touristic areas. Roatan is constantly receiving international cruise ships, with the consequent epidemiological implications, as above described. Now, in the department of Colon (with 506.3 cases/100,000 pop of chikungunya and 219.8 of dengue), which includes Trujillo (201.4 cases/100,000 pop of chikungunya and 107.1 of dengue) with its port Puerto Castilla, there is large industrial development with an international hub for cruise ships. This last, is also for consideration regard travel medicine and public health for these arboviral diseases in Honduras.

In the near future, maps for other clinical variables of these arboviral diseases should be developed in the country, including its incidence in children, women in childbearing age, pregnant women, patients with pCHIK-CIR, pCHIK-CIR associated DALYs, related costs, among others variables, that in fact have been mapped in other countries on Latin America, such as Colombia [17—19,26,27], with their consequent impacts on health information and potential implications in public health policy making. Detailed maps for Zika are now emerging from Colombia [38—40], among other countries and this should be followed by Honduras and other territories in Central and South America for a better understanding of these arboviral diseases.

Finally, preparedness on these arboviruses for healthcare workers and students in the Honduras and the region should go under intense continuing education activities [41,42], but more research interventions [43—45], including community participation on vector control will be necessary to control and mitigate the effects of *Aedes* transmission. Also, these first GIS-based epidemiological maps for dengue and chikungunya would be also useful in the future when planning for the development of trials with vaccine candidates, ongoing and now available in some countries for dengue [46—49], as well in the future for chikungunya and Zika [50,51].

Funding

Training on GIS for Alfonso J. Rodriguez-Morales was funded by Universidad Tecnológica de Pereira, Pereira, Risaralda, Colombia. This study is linked to the project ''Desarrollo de Mapas Epidemiológicos a través de Sistemas de Información Geográfica para la Caracterización Geográfica de Enfermedades Infecciosas y Tropicales en el Eje Cafetero de Colombia'' (Code 5-15-5 [2015—2017]), Universidad Tecnológica de Pereira, Pereira, Risaralda, Colombia. This study was partially presented as an oral dissertation at the 10th Congress of Scientific Research of the Universidad Nacional Autónoma de Honduras, Tegucigalpa, Honduras, August 2, 2016, being granted with the Shared Award for the

Excellence in Research, Category ''Improvement of Life Quality''.

Competing interests

None declared.

Ethical approval

Not required.

References

[1] Herrera-Martinez AD, Rodriguez-Morales AJ. Potential influence of climate variability on dengue incidence registered in a western pediatric hospital of Venezuela. Trop Biomed 2010;27(2):280—6.
[2] Rodriguez-Morales AJ, Paniz-Mondolfi AE. Venezuela: far from the path to dengue and chikungunya control. J Clin Virol 2015;66:60—1, http://dx.doi.org/10.1016/j.jcv.2015.02.020.
[3] Rodriguez-Morales AJ. Zika the new arbovirus threat for Latin America. J Infect Dev Countries 2015;9(6):684—5, http://dx.doi.org/10.3855/jidc.7230.
[4] Zambrano LI, Sevilla C, Reyes-Garcia SZ, Sierra M, Kafati R, Rodriguez-Morales AJ, et al. Potential impacts of climate variability on dengue hemorrhagic fever in Honduras, 2010. Trop Biomed 2012;29(4):499—507.
[5] Mlakar J, Korva M, Tul N, Popovic M, Poljsak-Prijatelj M, Mraz J, et al. Zika virus associated with microcephaly. N Engl J Med 2016;374(10):951—8, http://dx.doi.org/10.1056/NEJMoa1600651.
[6] Franco-Paredes C, Dismukes R, Nicolls D, Hidron A, Workowski K, Rodriguez-Morales A, et al. Persistent and untreated tropical infectious diseases among Sudanese refugees in the United States. Am J Trop Med Hyg 2007;77(4):633—5.
[7] Zamora A, Galan-Rodas E, Ramirez E, Rodriguez-Morales AJ, Mayta-Tristan P. Videogame Pitanga Town in the fight against dengue in Costa Rica. Rev Peru Med Exp Salud Publica 2015;32(2):397—8.
[8] Miller MJ, Loaiza JR. Geographic expansion of the invasive mosquito *Aedes albopictus* across Panama—implications for control of dengue and chikungunya viruses. PLoS Negl Trop Dis 2015;9(1):e0003383, http://dx.doi.org/10.1371/journal.pntd.0003383.
[9] Figueroa M, Pereira R, Gutierrez H, de Mejia C, Padilla N. Dengue epidemic in Honduras, 1978—1980. Bull Pan Am Health Organ 1982;16(2):130—7.
[10] Alfaro-Toloza P, Clouet-Huerta DE, Rodriguez-Morales AJ. Chikungunya, the emerging migratory rheumatism. Lancet Infect Dis 2015;15(5):510—2, http://dx.doi.org/10.1016/S1473-3099(15)70160-X.
[11] Buekens P, Alger J, Althabe F, Bergel E, Berrueta AM, Bustillo C, et al. Zika virus infection in pregnant women in Honduras: study protocol. Reprod Health 2016;13(1):82, http://dx.doi.org/10.1186/s12978-016-0200-6.
[12] Diaz Y, Carrera JP, Cerezo L, Arauz D, Guerra I, Cisneros J, et al. Chikungunya virus infection: first detection of imported and autochthonous cases in Panama. Am J Trop Med Hyg 2015;92(3):482—5, http://dx.doi.org/10.4269/ajtmh.14-0404.
[13] Rodriguez-Morales AJ, Cardona-Ospina JA, Villamil-Gomez W, Paniz-Mondolfi AE. How many patients with post-chikungunya chronic inflammatory rheumatism can we expect in the new endemic areas of Latin America? Rheumatol Int 2015;35(12):2091—4, http://dx.doi.org/10.1007/s00296-015-3302-5.
[14] Rodriguez-Morales AJ, Villamil-Gomez W, Merlano-Espinosa M, Simone-Kleber L. Post-chikungunya chronic arthralgia: a first retrospective follow-up study of 39 cases in Colombia. Clin Rheumatol 2016;35(3):831—2, http://dx.doi.org/10.1007/s10067-015-3041-8.
[15] Sanchez-Duque JA, Orozco-Hernandez JP, Rodriguez-Morales AJ. Rheumatic manifestations in patients with chikungunya infection: comment on the article by Arroyo-Avila and Vila. P R Health Sci J 2015;34(4):231—2.
[16] Rodriguez-Morales AJ, Calvache-Benavides CE, Giraldo-Gomez J, Hurtado-Hurtado N, Yepes-Echeverri MC, Garcia-Loaiza CJ, et al. Post-chikungunya chronic arthralgia: results from a retrospective follow-up study of 131 cases in Tolima, Colombia. Travel Med Infect Dis 2016;14(1):58—9, http://dx.doi.org/10.1016/j.tmaid.2015.09.001.
[17] Cardona-Ospina JA, Villamil-Gomez WE, Jimenez-Canizales CE, Castaneda-Hernandez DM, Rodriguez-Morales AJ. Estimating the burden of disease and the economic cost attributable to chikungunya Colombia, 2014. Trans R Soc Trop Med Hyg 2015;109(12):793—802, http://dx.doi.org/10.1093/trstmh/trv094.
[18] Cardona-Ospina JA, Diaz-Quijano FA, Rodriguez-Morales AJ. Burden of chikungunya in Latin American countries: estimates of disability-adjusted life-years (DALY) lost in the 2014 epidemic. Int J Infect Dis 2015;38:60—1, http://dx.doi.org/10.1016/j.ijid.2015.07.015.
[19] Cardona-Ospina JA, Rodriguez-Morales AJ, Villamil-Gomez WE. The burden of Chikungunya in one coastal department of Colombia (Sucre): estimates of the disability adjusted life years (DALY) lost in the 2014 epidemic. J Infect Public Health 2015;8(6):644—6, http://dx.doi.org/10.1016/j.jiph.2015.06.001.
[20] Stanaway JD, Shepard DS, Undurraga EA, Halasa YA, Coffeng LE, Brady OJ, et al. The global burden of dengue: an analysis from the Global Burden of Disease Study 2013. Lancet Infect Dis 2016;16(August (8)):935—41, http://dx.doi.org/10.1016/S1473-3099(16)00026-8.
[21] Villamil-Gomez WE, Gonzalez-Camargo O, Rodriguez-Ayubi J, Zapata-Serpa D, Rodriguez-Morales AJ. Dengue, chikungunya and Zika co-infection in a patient from Colombia. J Infect Public Health 2016;9(September—October (5)):684—6, http://dx.doi.org/10.1016/j.jiph.2015.12.002.
[22] Raut CG, Rao NM, Sinha DP, Hanumaiah H, Manjunatha MJ. Chikungunya, dengue, and malaria co-infection after travel to Nigeria, India. Emerg Infect Dis 2015;21(5):908—9, http://dx.doi.org/10.3201/eid2105.141804.
[23] Sardi S, Somasekar S, Naccache SN, Bandeira AC, Tauro LB, Campos GS, et al. Co-infections from Zika and Chikungunya virus in Bahia, Brazil identified by metagenomic next-generation sequencing. J Clin Microbiol 2016, http://dx.doi.org/10.1128/jcm.00877-16.
[24] Zambrano H, Waggoner JJ, Almeida C, Rivera L, Benjamin JQ, Pinsky BA. Zika virus and Chikungunya virus coinfections: a series of three cases from a single center in Ecuador. Am J Trop Med Hyg 2016, http://dx.doi.org/10.4269/ajtmh.16-0323.
[25] Quintero-Herrera LL, Ramirez-Jaramillo V, Bernal-Gutierrez S, Cardenas-Giraldo EV, Guerrero-Matituy EA, Molina-

Delgado AH, et al. Potential impact of climatic variability on the epidemiology of dengue in Risaralda Colombia, 2010—2011. J Infect Public Health 2015;8(3):291—7, http://dx.doi.org/10.1016/j.jiph.2014.11.005.

[26] Rodriguez-Morales AJ, Bedoya-Arias JE, Ramirez-Jaramillo V, Montoya-Arias CP, Guerrero-Matituy EA, Cardenas-Giraldo EV. Using geographic information system (GIS) to mapping and assess changes in transmission patterns of chikungunya fever in municipalities of the Coffee-Triangle region of Colombia during 2014—2015 outbreak: implications for travel advice. Travel Med Infect Dis 2016;14(1):62—5, http://dx.doi.org/10.1016/j.tmaid.2015.06.009.

[27] Rodriguez-Morales AJ, Cardenas-Giraldo EV, Montoya-Arias CP, Guerrero-Matituy EA, Bedoya-Arias JE, Ramirez-Jaramillo V, et al. Mapping chikungunya fever in municipalities of one coastal department of Colombia (Sucre) using geographic information system (GIS) during 2014 outbreak: implications for travel advice. Travel Med Infect Dis 2015;13(3):256—8, http://dx.doi.org/10.1016/j.tmaid.2015.05.007.

[28] Perich MJ, Sherman C, Burge R, Gill E, Quintana M, Wirtz RA. Evaluation of the efficacy of lambda-cyhalothrin applied as ultra-low volume and thermal fog for emergency control of *Aedes aegypti* in Honduras. J Am Mosq Control Assoc 2001;17(4):221—4.

[29] Clouet-Huerta D, Alfaro-Toloza P, Rodriguez-Morales AJ. Chikungunya in the Americas: preparedness, surveillance and alert in Chile. Rev Chilena Infectol 2014;31(6):761—2, http://dx.doi.org/10.4067/S0716-10182014000600022.

[30] Villamil-Gomez WE, Ramirez-Vallejo E, Cardona-Ospina JA, Silvera LA, Rodriguez-Morales AJ. Electrocardiographic alterations in patients with chikungunya fever from Sucre, Colombia: a 42-case series. Travel Med Infect Dis 2016, http://dx.doi.org/10.1016/j.tmaid.2016.06.004.

[31] Rodriguez-Morales AJ, Villamil-Gomez WE, Franco-Paredes C. The arboviral burden of disease caused by co-circulation and co-infection of dengue, chikungunya and Zika in the Americas. Travel Med Infect Dis 2016;14(3):177—9, http://dx.doi.org/10.1016/j.tmaid.2016.05.004.

[32] Rodriguez-Morales AJ, Granados-Alvarez S, Escudero-Quintero H, Vera-Polania F, Mondragon-Cardona A, Diaz-Quijano FA, et al. Estimating and mapping the incidence of giardiasis in Colombia. Int J Infect Dis 2016:2009—13, http://dx.doi.org/10.1016/j.ijid.2016.06.005.

[33] Christofferson RC. Zika virus emergence and expansion: lessons learned from dengue and Chikungunya may not provide all the answers. Am J Trop Med Hyg 2016;95(1):15—8, http://dx.doi.org/10.4269/ajtmh.15-0866.

[34] Chu HJ, Chan TC, Jao FJ. GIS-aided planning of insecticide spraying to control dengue transmission. Int J Health Geogr 2013;12:42, http://dx.doi.org/10.1186/1476-072X-12-42.

[35] Telle O, Vaguet A, Yadav NK, Lefebvre B, Daude E, Paul RE, et al. The spread of dengue in an endemic urban milieu-the case of Delhi, India. PLoS One 2016;11(1):e0146539, http://dx.doi.org/10.1371/journal.pone.0146539.

[36] Hamer D, Lichtveld M. Spatial distribution of epidemiological cases of dengue fever in Suriname, 2001—2012. West Indian Med J 2015;64(4), http://dx.doi.org/10.7727/wimj.2014.118.

[37] Nicoletti L, Ciccozzi M, Marchi A, Fiorentini C, Martucci P, D'Ancona F, et al. Chikungunya and dengue viruses in travelers. Emerg Infect Dis 2008;14(1):177—8, http://dx.doi.org/10.3201/eid1401.070618.

[38] Rodriguez-Morales AJ, Galindo-Marquez ML, Garcia-Loaiza CJ, Sabogal-Roman JA, Marin-Loaiza S, Ayala AF, et al. Mapping Zika virus infection using geographical information systems in Tolima, Colombia, 2015—2016. F1000Res 2016;5:568, http://dx.doi.org/10.12688/f1000research.8436.1.

[39] Rodriguez-Morales AJ, Patino-Cadavid LJ, Lozada-Riascos CO, Villamil-Gomez WE. Mapping Zika in municipalities of one coastal department of Colombia (Sucre) using geographic information systems during the 2015—2016 outbreak: implications for public health and travel advice. Int J Infect Dis 2016;48:70—2, http://dx.doi.org/10.1016/j.ijid.2016.05.012.

[40] Rodriguez-Morales AJ, Garcia-Loaiza CJ, Galindo-Marquez ML, Sabogal-Roman JA, Marin-Loaiza S, Lozada-Riascos CO, et al. Zika infection GIS-based mapping suggest high transmission activity in the border area of La Guajira Colombia, a northeastern coast Caribbean department, 2015—2016: implications for public health, migration and travel. Travel Med Infect Dis 2016;14(3):286—8, http://dx.doi.org/10.1016/j.tmaid.2016.03.018.

[41] Bedoya-Arias JE, Murillo-Garcia DR, Bolanos-Munoz E, Hurtado-Hurtado N, Ramirez-Jaramillo V, Granados-Alvarez S, et al. Healthcare students and workers' knowledge about epidemiology and symptoms of chikungunya fever in two cities of Colombia. J Infect Dev Countries 2015;9(3):330—2, http://dx.doi.org/10.3855/jidc.6445.

[42] Sabogal-Roman JA, Murillo-Garcia DR, Yepes-Echeverri MC, Restrepo-Mejia JD, Granados-Alvarez S, Paniz-Mondolfi AE, et al. Healthcare students and workers' knowledge about transmission, epidemiology and symptoms of Zika fever in four cities of Colombia. Travel Med Infect Dis 2016;14(1):52—4, http://dx.doi.org/10.1016/j.tmaid.2015.12.003.

[43] Vera-Polania F, Munoz-Urbano M, Banol-Giraldo AM, Jimenez-Rincon M, Granados-Alvarez S, Rodriguez-Morales AJ. Bibliometric assessment of scientific production of literature on chikungunya. J Infect Public Health 2015;8(4):386—8, http://dx.doi.org/10.1016/j.jiph.2015.03.006.

[44] Vera-Polania F, Perilla-Gonzalez Y, Martinez-Pulgarin DF, Baquero-Rodriguez JD, Munoz-Urbano M, Lagos-Gallego M, et al. Bibliometric assessment of the Latin-American contributions in dengue. Recent Pat Antiinfect Drug Discov 2014;9(3):195—201.

[45] Martinez-Pulgarin DF, Acevedo-Mendoza WF, Cardona-Ospina JA, Rodriguez-Morales AJ, Paniz-Mondolfi AE. A bibliometric analysis of global Zika research. Travel Med Infect Dis 2016;14(1):55—7, http://dx.doi.org/10.1016/j.tmaid.2015.07.005.

[46] Villar L, Dayan GH, Arredondo-Garcia JL, Rivera DM, Cunha R, Deseda C, et al. Efficacy of a tetravalent dengue vaccine in children in Latin America. N Engl J Med 2015;372(2):113—23, http://dx.doi.org/10.1056/NEJMoa1411037.

[47] Murugan K, Anitha J, Dinesh D, Suresh U, Rajaganesh R, Chandramohan B, et al. Fabrication of nano-mosquitocides using chitosan from crab shells: impact on non-target organisms in the aquatic environment. Ecotoxicol Environ Saf 2016;132:283—318.

[48] Villar LA, Rivera-Medina DM, Arredondo-Garcia JL, Boaz M, Starr-Spires L, Thakur M, et al. Safety and immunogenicity of a recombinant tetravalent dengue vaccine in 9—16 year olds: a randomized, controlled, phase II trial in Latin America. Pediatr Infect Dis J 2013;32(10):1102—9, http://dx.doi.org/10.1097/INF.0b013e31829b8022.

[49] Sarti E, L'Azou M, Mercado M, Kuri P, Siqueira Jr JB, Solis E, et al. A comparative study on active and passive epidemiological surveillance for dengue in five coun-

tries of Latin America. Int J Infect Dis 2016;44:44—9, http://dx.doi.org/10.1016/j.ijid.2016.01.015.

[50] Dyer O. Zika vaccine could be in production by year's end, says maker. BMJ 2016;352:i630, http://dx.doi.org/10.1136/bmj.i630.

[51] Deeba F, Islam A, Kazim SN, Naqvi IH, Broor S, Ahmed A, et al. Chikungunya virus: recent advances in epidemiology, host pathogen interaction and vaccine strategies. Pathog Dis 2016;74(3), http://dx.doi.org/10.1093/femspd/ftv119.