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Mapping Zika virus disease incidence in Valle del Cauca

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Abstract

Objective Geographical information systems (GIS) use for development of epidemiological maps in tropical diseases is increasingly frequently utilized. Here, we apply this technique to map the current Zika virus (ZIKV) outbreak in Colombia.

Methods Surveillance cases data of the ongoing epidemic of ZIKV in Valle del Cauca department and its capital, Cali (2015–2016), were used to estimate cumulated incidence rates (cases/100,000 population) to develop the first maps in the department and it municipalities. The GIS software used was Kosmo Desktop 3.0RC1®. Three thematic incidence rate maps were developed.

Results Up to April 2, 2016, 9,825 cases of ZIKV were reported (15.15 % of the country cases). The burden of ZIKV infection has been concentrated in the North of the department. Valle del Cauca borders with other departments with incidence of ZIKV infection, such as Quindío (173 cases) and Risaralda (687 cases). Eleven municipalities of Valle del Cauca had cases in the range between 250 and 499 cases/100,000, all in the North and East of the department. Cali, the capital concentrates more than a third of the reported cases of ZIKV in Valle del Cauca.

Conclusions Use of GIS-based epidemiological maps allows to guide decision-making for prevention and control of diseases that constitute significant public health problems in the region and the country, such as exemplified by the emergence of ZIKV infection, particularly in departments such as Valle del Cauca with a high disease incidence.

Keywords Zika · Epidemiology · Public health · Travelers · Colombia · Latin America

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Introduction

Zika virus (ZIKV) epidemics have significantly affected territories or countries in the Americas (46 as of September 2016) [1]. Although Colombia is not the country with the highest number of cases, which is Brazil, its cumulative incidence rate is higher (around 210 cases/100,000 in Colombia and 130 cases/100,000 in Brazil).

Some areas of Colombia are burdened with a high number of cases and incidence rates; particularly those less developed, in warmer areas, where previous epidemics
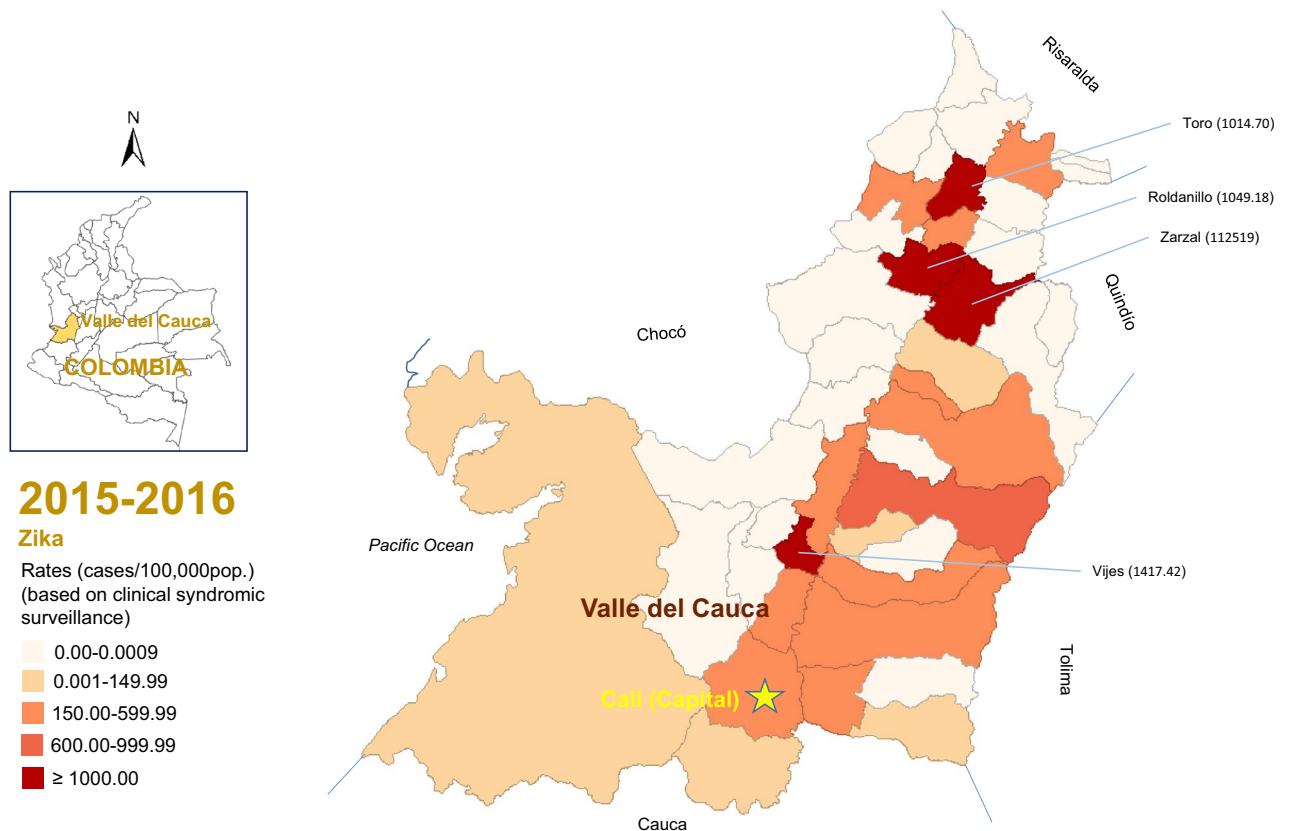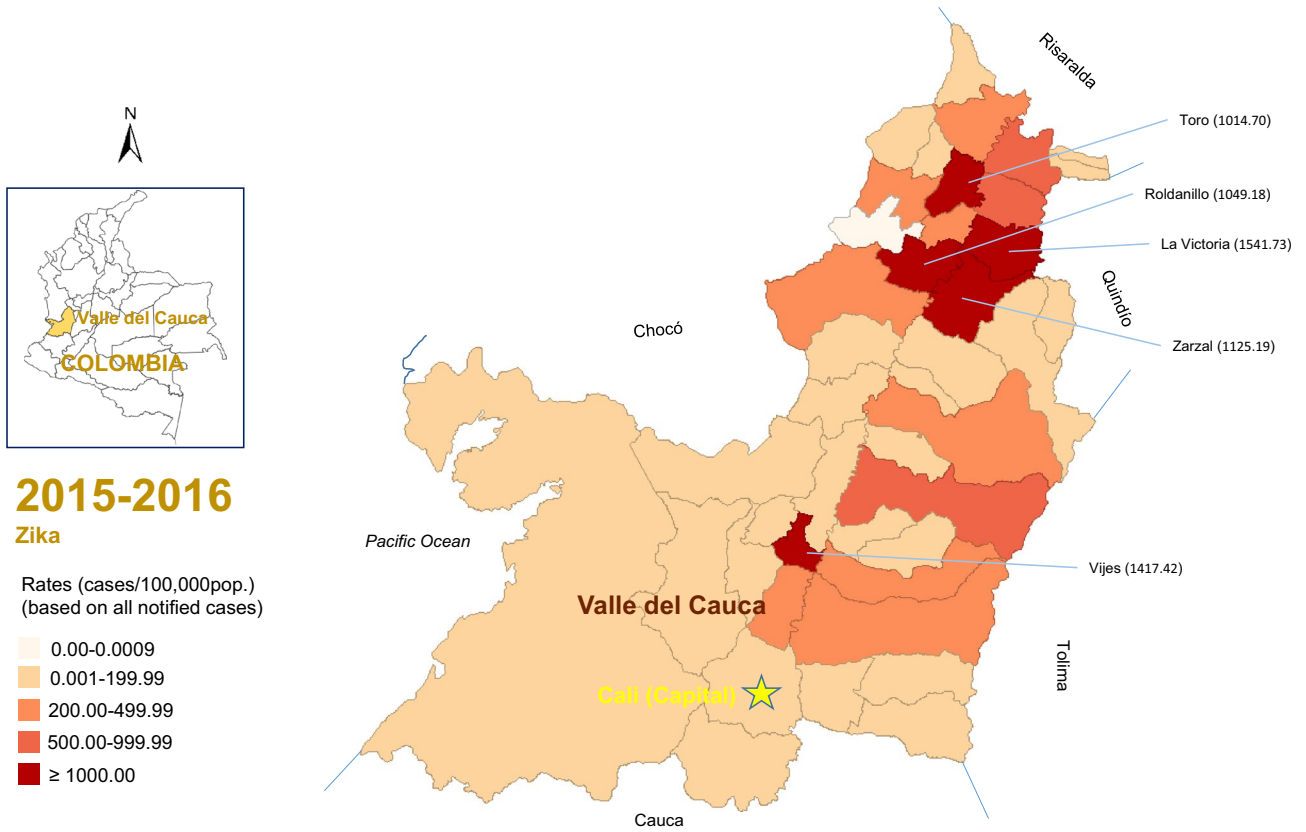
◄**Fig. 1** Geographic distribution of ZIKV incidence rates (cases/100,000 pop) in Valle del Cauca department, Colombia, 2015–2016, *upper*: based on all notified cases (total); *lower*: based on clinical syndromic surveillance (from municipalities with RT-PCR confirmed cases). *Asterisk* Up to epidemiological week 13th, April 2, 2016

of dengue and chikungunya (CHIKV) have occurred, and from where concomitant co-circulation of those arboviruses may occur [2, 3]. Nevertheless, it is important to notice that there is not epidemic of dengue and chikungunya during the current epidemic of Zika in Colombia.

Timely updated and location-specific epidemiological information of high resolution is most relevant, even for the definition of clinical sites in the future scenario of vaccine trials design. Epidemiological tools now include geographical information systems (GIS)-based mapping that allows to estimate the incidence rates and risk of infection by population per area. This enables to make recommendations related to prioritize interventions in population living in those areas as well as in visitors to, or people returning from visiting specific places [4, 5]. We have previously developed epidemiological maps for ZIKV in Colombia using geographical information systems (GIS) at high incidence departments, such as La Guajira and Sucre (Caribbean region), Tolima (Central area), Santander and Norte de Santander (Northeastern area) [6–9]. We have also previously provided GIS-based epidemiological maps for CHIKV in other areas of the country [5].

Methods

Scientific publications using GIS for development of epidemiological maps in ZIKV are still lacking in Latin America. Valle del Cauca is one of the significantly affected territories by the 2015–2016 outbreak. This is a department (first administrative territory level) surrounded by the Pacific Ocean and five other departments (one in the North, three in the West and one in the South of the country). It is constituted by 42 municipalities (second administrative territory level) (for a total population of 4,660,438 habitants for 2016, according to the national statistics department, www.dane.gov.co). Its capital, Santiago de Cali (or just simply Cali) municipality, includes 51.4 % of the population of the whole department. Cali is constituted by 23 communes (third administrative territory level).

Surveillance cases data (2015–2016) (officially reported to the National Institute of Health, Colombia) [10] were used to estimate the cumulative incidence rates using reference population data (2016), on ZIKV infections (cases/100,000) and to develop the first maps in the municipalities of Valle del Cauca and its capital, Cali, by communes. Data processed for this study stemmed from 42

primary notification units, one per municipality, and were later grouped and consolidated at the department level. In the case of the Cali municipality, data were collected from healthcare institutions of the 23 communes, and later consolidated at the municipality level. Determination of ZIKV infection includes either laboratory and syndromic surveillance (clinical definition of fever, rash, conjunctivitis and arthralgias in a municipality with previously ZIKV circulation, at least one case confirmed by RT-PCR). The clinical definition has been recommended by World Health Organization, Pan American Health Organization as well the US Centers for Disease Control and Prevention.

Total number of cases also included those in which clinical diagnostic criteria, i.e. the case definition was met, but which were reported in a municipality without RT-PCR confirmation. After one case is confirmed by RT-PCR in a municipality, patients not classified as risk groups (pregnant women, children <1 year old, people >60 year old and patients with comorbidity), can be diagnosed by clinical definition.

The software Microsoft Access® was the platform to design the spatial database used, to import incidence rates by municipalities in Valle del Cauca and communes at Cali to the GIS software. The Client GIS software open source used was Kosmo Desktop 3.0 RC1® (SAIG S.L., Spain). For the access to geographic data required and sharing results with institutions, support was provided by the spatial data infrastructure for the department by the Regional Information System of the Coffee-Triangle ecoregion. The shapefiles of municipalities and communes (.shp) were linked to a data table database through spatial joined operation, in order to produce digital maps of the incidence rates.

Results

Up to April 2, 2016, 9,825 cases of ZIKV were reported in Valle del Cauca (2.8 % diagnosed by RT-PCR for ZIKV), for cumulated rates of 211 cases/100,000 (15.15 % of the country). Rates ranged from 0 to 1542 cases/100,000 (La Victoria, 2.1 % of the department cases), followed by Vijes (1426 cases/100,000; 1.6 %), Zarzal (1130 cases/100,000; 5.3 %), Roldanillo (1055 cases/100,000; 3.5 %), Toro (1027 cases/100,000; 1.7 %) (Fig. 1). These five municipalities (out of 42), reported 14.2 % of cases of the department (Table 1). Four of them (Toro, Roldanillo, La Victoria and Zarzal) are located in the North of the department (Fig. 1), three of them neighboring each other (Roldanillo, La Victoria and Zarzal). The other (Vijes) neighbors Cali (Fig. 1). The capital municipality, Cali, has reported 3805 cases until April 2, 2016 (159 cases/100,000; 38.73 %) (Fig. 1). Other 13 municipalities reported incidence rates between

Table 1 ZIKV incidence rates (cases/100,000 pop) by municipalities in Valle del Cauca department, Colombia, 2015–2016

Municipalities	RT-PCR confirmed cases (2015–2016)	Clinical syndromic definition cases (CSD)		Total, Zika cases (2015–2016)	Population (2016)	Cumulative incidence rates, 2015–2016 (cases/100,000 pop)			
		From municipalities with RT-PCR cases (2015–2016)	From municipalities without RT-PCR cases (2015–2016)			Based on RT-PCR confirmed cases	Based on CSD from municipalities with RT-PCR confirmed cases	Based on CSD from municipalities without RT-PCR confirmed cases	Based on all cases (total)
Whole department	106	9037	682	9,825	4,660,438	2.27	193.91	14.63	210.82
La Victoria	0	0	203	203	13,167	0.00	0.00	1541.73	1541.73
Vijes	1	158	0	159	11,147	8.97	1417.42	0.00	1426.39
Zarzal	2	514	0	516	45,681	4.38	1125.19	0.00	1129.57
Roldanillo	2	342	0	344	32,597	6.14	1049.18	0.00	1055.31
Toro	2	167	0	169	16,458	12.15	1014.70	0.00	1026.86
Obando	0	0	100	100	15,059	0.00	0.00	664.05	664.05
Guad. De Buga	1	716	0	717	115,028	0.87	622.46	0.00	623.33
Cartago	3	737	0	740	132,966	2.26	554.28	0.00	556.53
Yumbo	13	554	0	567	119,889	10.84	462.09	0.00	472.94
Ansermanuevo	0	0	88	88	19,450	0.00	0.00	452.44	452.44
Bolivar	0	0	43	43	13,302	0.00	0.00	323.26	323.26
El Cerrito	1	168	0	169	57,749	1.73	290.91	0.00	292.65
La Union	1	110	0	111	38,351	2.61	286.82	0.00	289.43
Palmira	5	796	0	801	306,727	1.63	259.51	0.00	261.14
Tulua	10	477	0	487	214,081	4.67	222.81	0.00	227.48
Versalles	4	12	0	16	7,118	56.20	168.59	0.00	224.78
Yotoco	1	27	0	28	16,345	6.12	165.19	0.00	171.31
Andalucia	2	27	0	29	17,789	11.24	151.78	0.00	163.02
Cali	48	3757	0	3,805	2,394,870	2.00	156.88	0.00	158.88
Candelaria	1	130	0	131	82,898	1.21	156.82	0.00	158.03
Alcala	0	0	34	34	21,779	0.00	0.00	156.11	156.11
Argelia	0	0	9	9	6421	0.00	0.00	140.17	140.17
Pradera	0	0	58	58	55,831	0.00	0.00	103.88	103.88
El Cairo	0	0	9	9	10,050	0.00	0.00	89.55	89.55
San Pedro	0	0	16	16	18,383	0.00	0.00	87.04	87.04
Dagua	0	0	28	28	36,524	0.00	0.00	76.66	76.66
Ginebra	0	0	16	16	21,241	0.00	0.00	75.33	75.33
Bugalagrande	2	13	0	15	21,127	9.47	61.53	0.00	71.00

Table 1 continued

| Municipalities	RT-PCR confirmed cases (2015–2016)	Clinical syndromic definition cases (CSD)		Total, Zika cases (2015–2016)	Population (2016)	Cumulative incidence rates, 2015–2016 (cases/100,000 pop)			
		From municipalities with RT-PCR cases (2015–2016)	From municipalities without RT-PCR cases (2015–2016)			Based on RT-PCR confirmed cases	Based on CSD from municipalities with RT-PCR confirmed cases	Based on CSD from municipalities without RT-PCR confirmed cases	Based on all cases (total)
Riofrio	0	0	10	10	14,489	0.00	0.00	69.02	69.02
Restrepo	0	0	11	11	16,272	0.00	0.00	67.60	67.60
Trujillo	0	0	12	12	18,041	0.00	0.00	66.52	66.52
Buenaventura	2	262	0	264	407,539	0.49	64.29	0.00	64.78
Caicedonia	0	0	18	18	29,726	0.00	0.00	60.55	60.55
El Aguila	0	0	6	6	11,115	0.00	0.00	53.98	53.98
Guacari	1	16	0	17	34,796	2.87	45.98	0.00	48.86
Ulloa	0	0	2	2	5,421	0.00	0.00	36.89	36.89
Florida	1	19	0	20	58,342	1.71	32.57	0.00	34.28
Jamundi	2	35	0	37	122,030	1.64	28.68	0.00	30.32
La Cumbre	0	0	3	3	11,562	0.00	0.00	25.95	25.95
Calima	0	0	4	4	15,794	0.00	0.00	25.33	25.33
Sevilla	0	0	6	6	44,876	0.00	0.00	13.37	13.37
El Dovio	0	0	0	0	8407	0.00	0.00	0.00	0.00
Unknown	1	0	6	7	–	–	–	–	–

Up to epidemiological week 13th, April 2, 2016

Table 2 ZIKV incidence rates (cases/100,000 pop) ratio of municipalities in Valle del Cauca department municipalities, Colombia, 2015–2016, compared with the department and Cali incidence rates

Municipalities	Global rate	Rates ratio compared to department	Rates ratio compared to Cali municipality
Whole department	210.82	–	–
La Victoria	1541.73	7.31	9.70
Vijes	1426.39	6.77	8.98
Zarzal	1129.57	5.36	7.11
Roldanillo	1055.31	5.01	6.64
Toro	1026.86	4.87	6.46
Obando	664.05	3.15	4.18
Guad. De Buga	623.33	2.96	3.92
Cartago	556.53	2.64	3.50
Yumbo	472.94	2.24	2.98
Ansermanuevo	452.44	2.15	2.85
Bolivar	323.26	1.53	2.03
El Cerrito	292.65	1.39	1.84
La Union	289.43	1.37	1.82
Palmira	261.14	1.24	1.64
Tulua	227.48	1.08	1.43
Versalles	224.78	1.07	1.41
Yotoco	171.31	0.81	1.08
Andalucia	163.02	0.77	1.03
Cali	158.88	0.75	–
Candelaria	158.03	0.75	0.99
Alcala	156.11	0.74	0.98
Argelia	140.17	0.66	0.88
Pradera	103.88	0.49	0.65
El Cairo	89.55	0.42	0.56
San Pedro	87.04	0.41	0.55
Dagua	76.66	0.36	0.48
Ginebra	75.33	0.36	0.47
Bugalagrande	71.00	0.34	0.45
Riofrio	69.02	0.33	0.43
Restrepo	67.60	0.32	0.43
Trujillo	66.52	0.32	0.42
Buenaventura	64.78	0.31	0.41
Caicedonia	60.55	0.29	0.38
El Aguila	53.98	0.26	0.34
Guacari	48.86	0.23	0.31
Ulloa	36.89	0.18	0.23
Florida	34.28	0.16	0.22
Jamundi	30.32	0.14	0.19
La Cumbre	25.95	0.12	0.16
Calima	25.33	0.12	0.16
Sevilla	13.37	0.06	0.08
El Dovio	0.00	0.00	0.00

163 and 664 cases/100,00. These 18 territories together with the capital reported more than 92 % of the ZIKV cases of the department of Valle del Cauca (Table 1).

Ten of the municipalities have rates that are >2 times higher than the incidence rate of the department (incidence rates ratio) (Table 2). The rates ratio between Cali and Valle
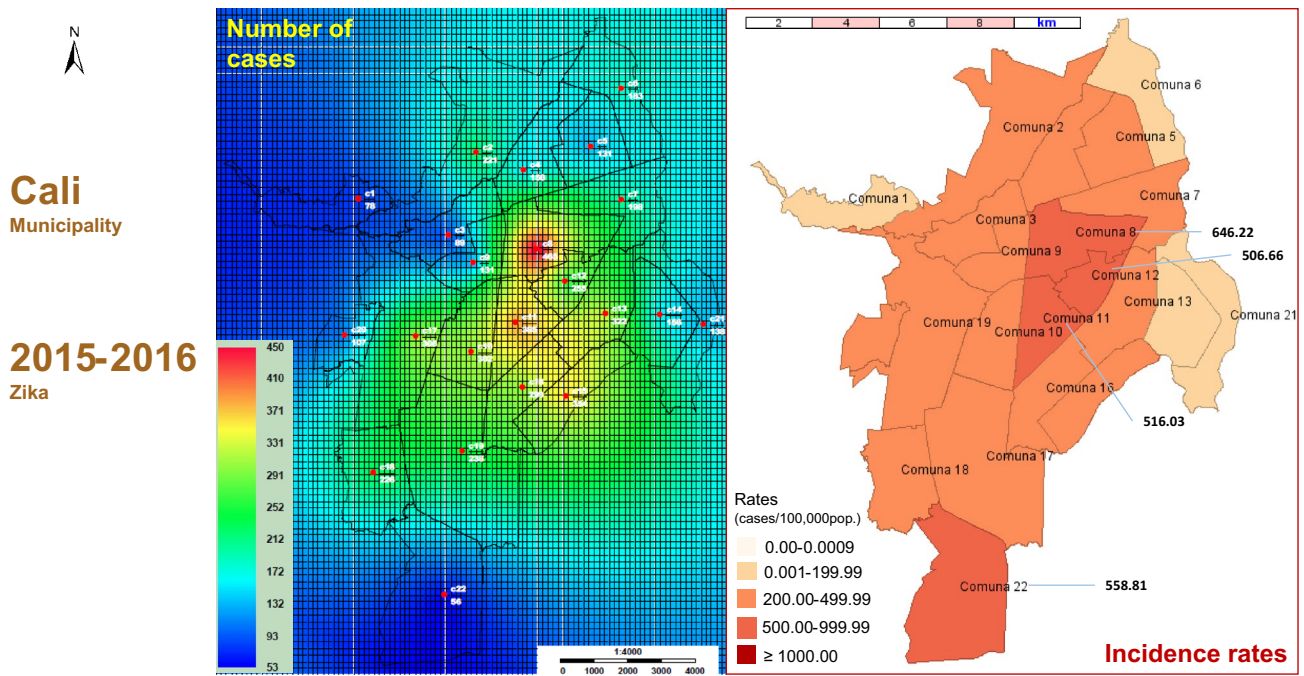
Fig. 2 Geographic distribution of ZIKV cases and incidence rates per communes (cases/100,000 pop) in Cali municipality, Valle del Cauca department, Colombia, 2015–2016

del Cauca is 0.75. Eleven of the municipalities have rates that are >2 times higher than the incidence rate of Cali (Table 2).

Colombia officially has reported a total of 64,839 cases (up to the 13th epidemiological week of 2016); more than 15 % from Valle del Cauca (9825). Burden of ZIKV infection has been concentrated in its Northern area, were municipalities have reported >1000 cases/100,000pop (1 %). One of them borders with the department of Quindío (173 cases), also they are close to Risaralda (687 cases), with much lower incidence of ZIKV infection (Fig. 1). Eleven municipalities ranged 250–499.99 cases/100,000, in the north and east of the department. Cali, the capital concentrates more than a third of the reported cases of ZIKV in Valle del Cauca (38.7 %).

Until May 14, 2016, there were 7449 cases in Cali. For its communes, rates ranged from 126.12 to 646.22 cases/100,000 pop. (commune 8, 8.56 % of the municipality's cases, located at the center of the municipality) (Fig. 2), followed by commune 22 (558.81 cases/100,000 pop.; 0.83 %), commune 11 (516.03 cases/100,000 pop.; 7.19 %) and commune 12 (506.66 cases/100,000 pop.; 4.36 %). The communes 8, 11 and 12 are bordering between them, them concentrating 20.11 % of the city cases (561.95 cases/100,000. together). Eighteen surrounding communes had incidence rates ranging between 200 and 499.99 cases/100,000 pop. (Table 3; Fig. 2).

Discussion

Given the ecoepidemiological conditions, such as warmer temperatures during the whole year, high number of susceptible individuals and high presence of vectors, particularly in some municipalities, those are now becoming endemic for ZIKV. Among cases in Valle del Cauca, 981 (9.98 %) were in pregnant women (59 confirmed by RT-PCR for ZIKV) [10]. Also, more than 64 % of them have been diagnosed during the first trimester (with more than >37 % being less than 25 years old, >11 % less than 20 years old). Unfortunately, only 3 % of cases have been confirmed by RT-PCR. This is related to economical limitations that does not allow to assess all the patients by laboratory (not affordable) and because still there is lack of reliable serological tests. Nevertheless, also Pan American Health Organization use in surveillance cases that have been reported based just on clinical definition.

Particularly, detailed evaluation of morbidity among pregnant women and its mapping due to this arbovirus should be performed, given the potential negative outcomes in terms of the Zika congenital syndrome, including central nervous systems birth defects [11, 12]. There is an enhanced number of ZIKV-associated neurological syndromes with 25 cases reported from Valle del Cauca as well one case of acute flaccid paralysis with history of ZIKV infection [10]. Then, public health policies and strategies

Table 3 ZIKV incidence rates (cases/100,000 pop) by communes in Cali, Valle del Cauca, Colombia, 2015–2016

Cali communes	Cases (2015–2016)	Population (2016)	Rates (cases/100,000 pop.)
8	663	102,597	646.22
22	64	11,453	558.81
11	557	107,940	516.03
12	338	66,712	506.66
9	218	44,645	488.30
16	513	108,183	474.20
4	239	53,052	450.50
10	481	111,296	432.18
7	262	70,819	369.96
17	488	142,914	341.46
15	552	162,439	339.82
19	377	113,898	331.00
3	147	46,517	316.01
2	343	116,586	294.20
18	359	135,199	265.53
13	454	178,052	254.98
20	163	69,677	233.94
5	234	113,010	207.06
21	218	114,270	190.78
6	308	191,529	160.81
1	138	91,352	151.06
14	220	174,441	126.12

for integral control of ZIKV in people living, but also in visitors [4–8, 13] to those areas, should be considered and urgently implemented; particularly in the capital, Cali, and in the Northern municipalities. In Cali, as well as Valle del Cauca, other arboviruses, such as dengue and chikungunya are also cocirculating [14]. In the capital, Cali, cases are concentrated in three center communes (8, 11 and 12), where 0.5 % of the population have been affected during the ongoing epidemics. Even more, these communes comprise more than 11.5 % of the city's population.

Eleven municipalities of Valle del Cauca had cases in the range between 250 and 499 cases/100,000, all in the North and East of the department. This could be explained in part with the mobility in this area of the department as well as with shared climatic and ecological conditions, suitable for vector and non-vector transmission of ZIKV.

Among municipalities with >250 cases/100,000 pop, is included Palmira, where the International Airport Alfonso Bonilla Aragon, serving Cali, is located. This airport is the main in the whole south-western area of Colombia. This hub includes flights to Miami and New York (JFK) (USA), San Salvador (El Salvador), Panama (Panama), Esmeraldas and Guayaquil (Ecuador), Lima (Peru), Madrid (Spain) and Amsterdam (Netherlands). This could have implications for travel medicine and should be considered when assessing the risk of international spread and related measures.

Although ZIKV was first isolated in 1947 in Central Africa [1], significant research has been conducted for the first time during the past months (ending 2015–beginning 2016) [15], in countries particularly such as Brazil and in Colombia, due to the recent emergence in the Americas.

Use of GIS-based epidemiological maps allow to integrate preventive and control strategies, as well as public health policies, for joint control of this vector-borne disease in this and other areas of the country [4–9, 16–24]. As other arboviruses are co-circulating (dengue, CHIKV and ZIKV), maps of them as well for co-infections will be also needed [16, 17]. Simultaneous or subsequent arboviral infections occur and should also be assessed. Preparedness in this setting should also consider the potential arrival of Mayaro and Yellow Fever in *Aedes* infested areas [25, 26]. Nevertheless, there is the need for better case definition criteria, including newer microbiological laboratory diagnosis techniques, that allows the differentiation of the involved infectious agents also in order to create virus-specific epidemiological maps.

In this setting use of GIS would be also at national and subnational levels to provide models about the influence and suitability of Zika given environmental and social factors [8, 18]. Recent evidences indicated that 2015 El Niño caused extreme climatic conditions in Northeastern South America during winter and spring in the southern

hemisphere, that might have contributed to the rapid dispersal of Zika virus in Brazil and other countries in the region, possibly including Colombia [19], as has been evidenced for dengue in different regions of this country [20, 21]. Also, entomological surveillance, in airports, such the Cali's one located in Palmira, should be enhanced, given the associated risks for imported case, even to other countries, but also importation of infected and non-infected mosquito vectors.

Finally, maps provide relevant information in order to assess the risk of travelers to specific destinations in highly transmission areas allowing detailed prevention advices [13, 22–24]. These interventions would be even on real time and cost-effective for early control activities [27]. They would also play an important role in the virus spread assessment [4–9, 13] as in Colombia and its Valle del Cauca department in 2015–2016.

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