



RESEARCH NOTE

Mapping Zika virus infection using geographical information systems in Tolima, Colombia, 2015-2016 [version 1; referees: 2 approved]

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Abstract

Objective: Geographical information systems (GIS) have been extensively used for the development of epidemiological maps of tropical diseases, however not yet specifically for Zika virus (ZIKV) infection.

Methods: Surveillance case data of the ongoing epidemics of ZIKV in the Tolima department, Colombia (2015-2016) were used to estimate cumulative incidence rates (cases/100,000 pop.) to develop the first maps in the department and its municipalities, including detail for the capital, Ibagué. The GIS software used was Kosmo Desktop 3.0RC1®. Two thematic maps were developed according to municipality and communes incidence rates.

Results: Up to March 5, 2016, 4,094 cases of ZIKV were reported in Tolima, for cumulated rates of 289.9 cases/100,000 pop. (7.95% of the country). Burden of ZIKV infection has been concentrated in its east area, where municipalities have reported >500 cases/100,000 pop. These municipalities are bordered by two other departments, Cundinamarca (3,778 cases) and Huila (5,338 cases), which also have high incidences of ZIKV infection. Seven municipalities of Tolima ranged from 250-499.99 cases/100,000 pop., of this group five border with high incidence municipalities (>250), including the capital, where almost half of the reported cases of ZIKV in Tolima are concentrated.

Conclusions: Use of GIS-based epidemiological maps helps to guide decisions for the prevention and control of diseases that represent significant issues in the region and the country, but also in emerging conditions such as ZIKV.

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Referee Status:

Invited Referees		
	1	2
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Introduction

Zika virus (ZIKV) epidemics are progressing across most of the territories of Latin America without effective control¹. In particular, some areas of Colombia are being impacted with a high incidence of cases, nevertheless without show their incidence rates and detailed geographical distribution in most reports. Areas where cocirculation of dengue and chikungunya have occurred^{2,3}, are particularly at risk. In this setting updated epidemiological information is of utmost importance, which should include the availability of risk maps in order to address recommendations to prioritize interventions as well for the identification of areas of risk by visitors or people returning from visiting specific places^{4,5}. Accordingly, we have developed epidemiological maps for ZIKV in Colombia using geographical information systems (GIS) at one of the high incidence departments (Tolima) located in the central area of the country. We have previously provided GIS-based epidemiological maps for CHIKV in other areas of the country⁵.

Methods

Scientific publications using GIS for development of epidemiological maps in ZIKV lack in Latin America and Colombia. Tolima, a department surrounded by seven departments (five at the west and two at the east) with 47 municipalities (for a total population of 1,412,230 habitants) is one of the territories significantly affected by the 2015–2016 outbreak. Its capital, the Ibagué municipality, constitutes 13 urban communes and a rural area, comprising 39.6% of the total population of the department.

Surveillance case data (2015–2016; officially reported by the National Institute of Health, Colombia)⁶ were used to estimate the cumulative incidence rates using reference population data (2016), on ZIKV infections (cases/100,000 pop.) and to develop the first maps in the municipalities of Tolima and in the communes of the Ibagué municipality. Data for this study were gathered from 47 primary notification units, one per municipality, and later consolidated at the department level. In the case of the Ibagué municipality, data were collected from healthcare institutions of the 13 communes, and later consolidated at the municipality level. Diagnosis of ZIKV infection included either laboratory and/or 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 software Microsoft Access (version 365)® was used to design the spatial database, and to import incidence rates for municipalities in Tolima and communes in Ibagué to the GIS software. The open source GIS software used was Kosmo Desktop 3.0 RC1®. Geographic data (municipalities and department polygons) required for the department and the Ibagué municipality were provided by the Regional Information System of the Coffee-Triangle region. The shapefiles (based on official cartography) of municipalities and communes (.shp) were linked to the data table database through a spatial join operation, in order to produce digital maps of the incidence rates.

Results

Dataset 1. Raw data for 'Mapping Zika virus infection using geographical information systems in Tolima, Colombia, 2015–2016'

<http://dx.doi.org/10.5256/f1000research.8436.d118256>

Up to March 5, 2016, 4,094 cases of ZIKV were reported in Tolima (5.93% diagnosed by RT-PCR for ZIKV), for cumulative rates of 289.9 cases/100,000 pop. (7.95% of the country). Rates ranged from 0 to 1,120.5 cases/100,000 pop. (Carmen de Apicalá, 2.4% of the department cases), followed by Dolores (786.0 cases/100,000 pop.; 1.5%), Piedras (780.1 cases/100,000 pop.; 1.1%), Flandes (760.3 cases/100,000 pop.; 5.4%), Melgar (693.5 cases/100,000 pop.; 6.2%) (Figure 1). These five municipalities (out of 47), reported 16.61% of cases of the department (Table 1). The capital municipality, Ibagué have reported 2,004 cases (358.6 cases/100,000 pop.; 48.9%) (Figure 1). The other five municipalities reported incidence rates between 387.3 and 469.2 cases/100,000 pop. These ten territories together with the capital reported more than 83% of the ZIKV cases in the department of Tolima (Table 1).

For the Ibagué communes, rates ranged from 43.64 (rural area) to 514.52 cases/100,000 pop. (commune 7, 10.88% of the municipality's cases, located at the east of the municipality) (Figure 2), followed by commune 9 (375.19 cases/100,000 pop.; 11.73%) and commune 12 (358.79 cases/100,000 pop.; 7.53%). These three communes do not share a common border. The other eight communes had incidence rates ranging between 250–499.99 cases/100,000 pop. (Table 1, Figure 2). Only three communes had rates higher than the whole Ibagué municipality and of them, only one with a rate >500 cases/100,000 pop. (commune 7) (Table 1, Figure 2). Five communes (7, 9, 12, 8 and 4) concentrated more than 50% of the cases of the Ibagué municipality and more than 25% of the whole department (Table 1).

Colombia have officially reported a total of 51,473 cases (up to the 9th epidemiological week of 2016); almost 8% from Tolima (4,094). There, burden of ZIKV infection has been concentrated in its east area, were those municipalities with >500 cases/100,000 pop. border two other departments, Cundinamarca (3,778 cases) and Huila (5,338 cases), also with high incidences of ZIKV infection (Figure 1). Seven municipalities ranged from 250–499.99 cases/100,000 pop., of them five border with high incidence municipalities, including the capital where almost half of the reported cases of ZIKV in Tolima are concentrated (Figure 1).

Discussion

Given the ecoepidemiological conditions, particularly of these municipalities, they are now becoming endemic for ZIKV. They have been also endemic of dengue and CHIKV⁷. Among ZIKV cases in Tolima, 427 (10.43%) were in pregnant women

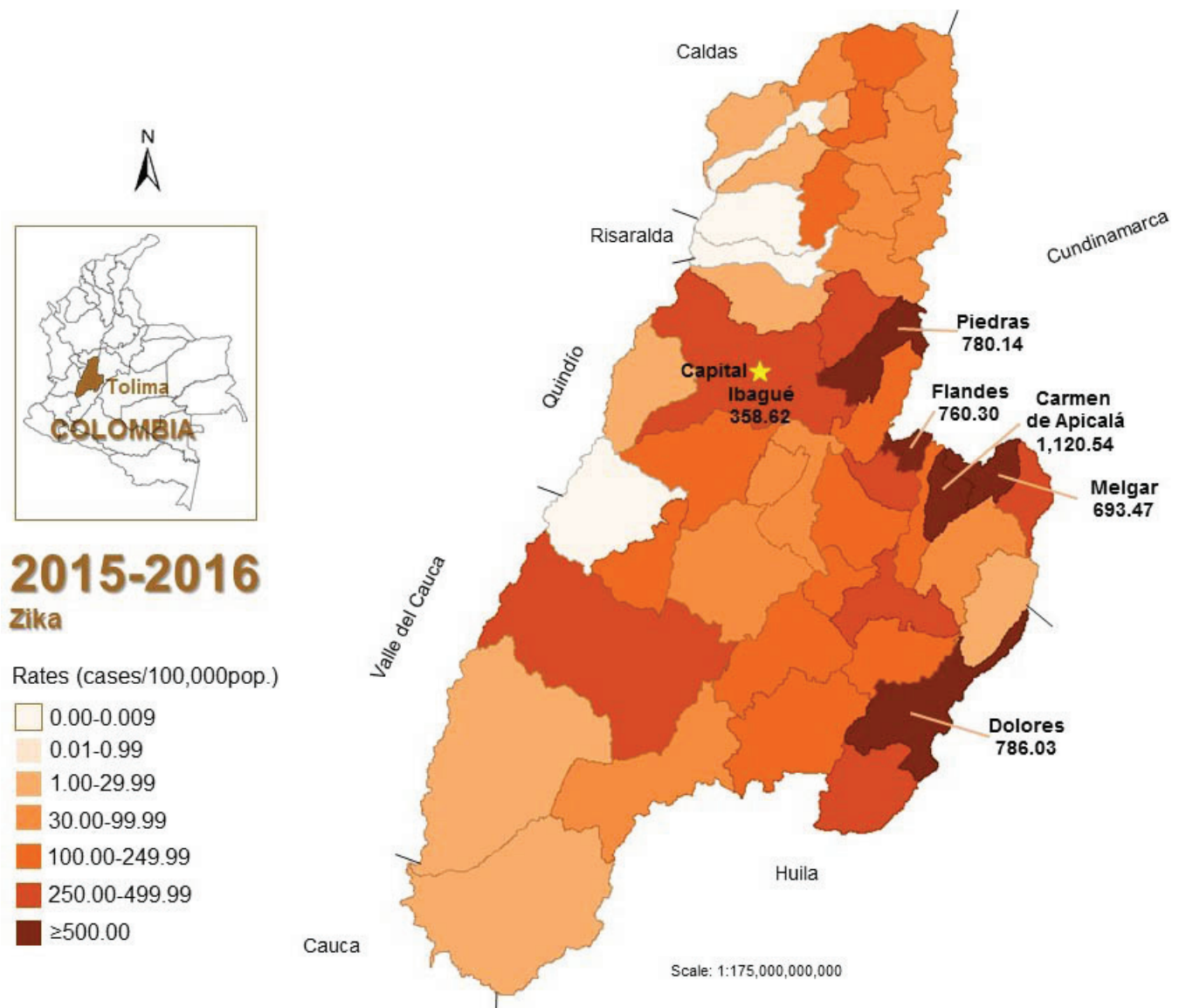


Figure 1. Geographic distribution of ZIKV incidence rates (cases/100,000 pop.) in the Tolima department, Colombia, 2015–2016. (*Up to the 9th epidemiological week, March 5, 2016).

(28 confirmed by RT-PCR for ZIKV)⁶. Particularly, detailed evaluation of pregnant women morbidity and its mapping due to this arbovirus should be performed^{8,9}. Even more, the enhanced surveillance of ZIKV-associated neurological syndromes reported eight cases in Tolima as well as three cases of acute flaccid paralysis with history of ZIKV infection⁶. Public health policies and strategies for integral control of ZIKV in people living, but also in visitors¹⁰, in these areas, should be considered and urgently

implemented, particularly in the capital, Ibagué. At Ibagué, as well as Tolima, other arboviruses, such as dengue and chikungunya are also cocirculating.

Although ZIKV was isolated in 1947¹, only significant research has been done during the past months (ending 2015–beginning 2016)¹¹, in countries such as Brazil and Colombia in particular, due to multiple negative potentially linked outcomes.

Table 1. ZIKV incidence rates (cases/100,000 pop.) by municipality in the Tolima department and Ibagué communes, Colombia, 2015–2016.*

Municipality*	Cases (2015–2016)	% Cumulated	Population (2016)	Rates (cases/100,000 pop.)
Whole department	4,094	100.0	1,412,230	289.9
Carmen de Apicalá	99	2.42	8,835	1,120.5
Dolores	63	3.96	8,015	786.0
Piedras	44	5.03	5,640	780.1
Flandes	222	10.45	29,199	760.3
Melgar	252	16.61	36,339	693.5
Purificación	138	19.98	29,412	469.2
Espinal	343	28.36	76,149	450.4
Icononzo	48	29.53	10,894	440.6
Alvarado	37	30.43	88,16	419.7
Chaparral	183	34.90	47,248	387.3
Ibagué	2,004	83.85	558,815	358.6
Alpujarra	13	84.17	4,974	261.4
Lerida	42	85.20	17,395	241.4
Guamo	76	87.05	32,113	236.7
Prado	18	87.49	7,701	233.7
Natagaima	49	88.69	22,516	217.6
Coello	18	89.13	9,810	183.5
Suarez	8	89.33	4,547	175.9
Saldaña	25	89.94	14,385	173.8
Coyaima	47	91.08	28,335	165.9
Rovira	34	91.91	20,542	165.5
Mariquita	54	93.23	33,329	162.0
Falan	14	93.58	9,211	152.0
San Antonio	21	94.09	14,310	146.8
Valle del San Juan	6	94.24	6,368	94.2
Cunday	9	94.46	9,634	93.4
Ambalema	6	94.60	6,755	88.8
Honda	21	95.11	24,547	85.6
Ataco	19	95.58	22,589	84.1
San Luis	14	95.92	19,153	73.1
Ortega	18	96.36	32,431	55.5
Armero				
(Guayabal)	6	96.51	11,839	50.7
Libano	17	96.92	40,266	42.2
Venadillo	7	97.09	19,652	35.6
Fresno	10	97.34	30,165	33.2

Municipality*	Cases (2015–2016)	% Cumulated	Population (2016)	Rates (cases/100,000 pop.)
Cajamarca	5	97.46	19,641	25.5
Villahermosa	2	97.51	10,652	18.8
Villarrica	1	97.53	5,389	18.6
Herveo	1	97.56	8,008	12.5
Palocabildo	1	97.58	9,160	10.9
Planadas	3	97.66	29,974	10.0
Rioblanco	2	97.70	24,459	8.2
Anzoategui	1	97.73	18,638	5.4
Casabianca	0	97.73	6,661	0.0
Murillo	0	97.73	5,018	0.0
Roncesvalles	0	97.73	6,344	0.0
Santa Isabel	0	97.73	6,357	0.0
Unknown	93	100.00	-	-
Ibagué commune*	Cases (2015–2016)	% Cumulated	Population (2016)	Rates (cases/100,000 pop.)
7	218	10.88	42,370	514.52
9	235	22.60	62,635	375.19
12	151	30.14	42,085	358.79
8	270	43.61	76,141	354.60
4	153	51.25	43,186	354.28
6	171	59.78	48,770	350.63
5	99	64.72	28,902	342.53
11	99	69.66	29,262	338.32
1	97	74.50	30,450	318.56
3	70	77.99	23,426	298.81
13	47	80.34	15,953	294.62
10	96	85.13	42,558	225.57
2	84	89.32	40,997	204.89
Rural area	14	90.02	32,080	43.64
Unknown	200	100.00	-	-

*Up to epidemiological week 9th, March 5, 2016

Use of GIS-based epidemiological maps allows for the integration of 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^{4,5}. As other arboviruses are cocirculating (dengue, CHIKV and ZIKV), maps for each as well as for coinfections are needed^{12,13}. Simultaneous or subsequent arboviral infections occur and should be

also assessed. Preparedness in this setting should also consider the potential arrival of Mayaro and yellow fever in *Aedes* infested areas. Finally, maps provide relevant information in order to assess the risk of travelers to specific destinations in high transmission areas allowing detailed prevention advice. Migrant and traveler populations also play an important role in the virus spread as they would

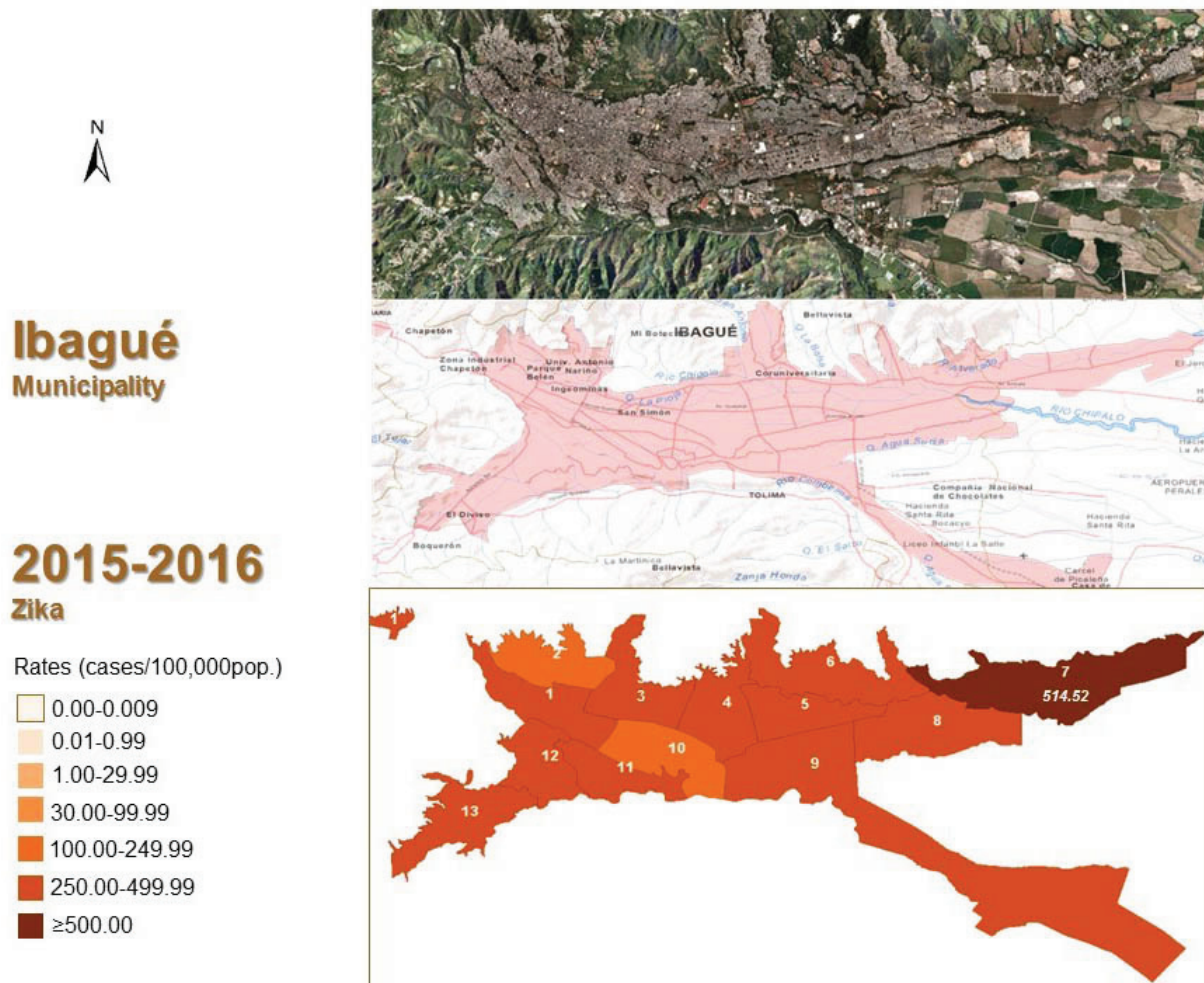


Figure 2. Geographic distribution of ZIKV incidence rates (cases/100,000 pop.) in Ibagué municipality, Colombia, 2015–2016. (*Up to the 9th epidemiological week, March 5, 2016). Aerial photography obtained from the Geographical Institute Agustín Codazzi, Colombia, at: <http://ssiglups.igac.gov.co/ssigl2.0/visor/galeria.req?mapaId=44>

arrive viremic from endemic areas to non-endemic areas, with vectors that may allow transmission to susceptible individuals^{4,5,10}, as occurred in Colombia (including the Tolima department) in 2015–2016.

Ethics

This study was approved by the Secretary of Health of Tolima IRB as not requiring ethics approval given the study is about secondary grouped data.

Data availability

F1000Research: Dataset 1. Raw data for ‘Mapping Zika virus infection using geographical information systems in Tolima, Colombia, 2015–2016’, [10.5256/f1000research.8436.d118256](https://doi.org/10.5256/f1000research.8436.d118256)¹⁴

Author contributions

Study design: AJRM, Data collection: MLGM, CJGL, JASR, SML, AFA, COLR, ASO, Data analysis: AJRM, COLR, Writing: All authors. All authors read the final version submitted.

Competing interests

There is no conflict of interest.

Grant information

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I confirm that the funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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[Data Source](#)

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Version 1

Referee Report 13 April 2016

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Luis Haro-García

Department of Public Health, Faculty of Medicine, National Autonomous University of Mexico, Mexico City, Mexico

The manuscript illustrated—through geographic mapping—the epidemiological behavior of Zika virus infection in the municipality of Tolima, Colombia, which results in an easy and understandable way for the decision makers in order to face an emerging problem like the one analyzed.

I think the title and the abstract are accurate; the methodology clearly stands that the study was conducted at one of the high incidence departments located in the central area of Colombia. In general, I think the results are arranged clearly enough; besides, the findings in the municipality of Ibagué, capital of the municipality, given that it comprising almost 40% of the total population of the department, the data are shown independently

It would be desirable at a given moment to develop this same method of mapping conjointly with the municipalities of Cundinamarca and Huila, bordering areas with Tolima, Colombia, where there was also a high incidence of Zika virus infection, at least until March 5, 2016.

The article highlights, in a balanced manner, the advantages of performing this type of mapping, considering that the authors also note the area on study as endemic for dengue and chikungunya.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Competing Interests: No competing interests were disclosed.

Author Response 14 Apr 2016

Alfonso Rodriguez-Morales, Universidad Tecnológica de Pereira, Colombia

Thanks for your valuable and positive comments regard this paper. We fully agree with about the assessment of Cundinamarca and Huila Zika incidence rates, given the fact these are bordering areas with Tolima, Colombia, where there was also a high incidence of Zika virus infection. In a future paper we will perform that for those other areas of the country.

Competing Interests: None.

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Kateryna Kon

Department of Microbiology, Virology and Immunology, Kharkiv National Medical University, Kharkiv, Ukraine

The article provides very interesting information on geographical mapping of Zika virus in Tolima (Colombia). The title and abstract are totally appropriate and represent an adequate summary of the article. There is a comprehensive explanation of the study design with detail description of all methods used, and with appropriate citations. Results are well illustrated in table and figures, and the article is written in grammatically correct and well-understandable scientific language. The conclusions are balanced and totally justified on the basis of the results. All sufficient information has been provided for replication of calculations performed by authors. For the further researches, it would be interesting to compare provided by authors results with results obtained in other areas of Colombia and with results from other countries of Latin America.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Competing Interests: No competing interests were disclosed.

Author Response 06 Apr 2016

Alfonso Rodriguez-Morales, Universidad Tecnológica de Pereira, Colombia

Thanks for your comments. We fully agree with all your appreciations. In the near future, when other similar studies would be published we expect to make those comparisons.

Competing Interests: None