Mortality by cause of death in Colombia 1998-2014: A local analysis using spatial econometrics

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Abstract

Colombia has undergone major changes in mortality patterns during the last decade, in particular due to reductions in external causes. This has had a significant impact on excess deaths in young adult males. While cause-specific analyses have been performed at the national and, to a lesser extent, departmental level, very little is known about trends at the municipal level, despite their great epidemiological interest. Our objective in this paper is therefore to identify geographic clusters of mortality in Colombia and their evolution over time that will allow decision makers to prioritize those regions with higher mortality. To do so, we will use Exploratory Spatial Data Analysis (ESDA) to analyse several large groups of causes: infectious diseases, tumors, cardiovascular diseases, perinatal mortality, external causes, ill-defined causes and remaining causes.

The study analyzes trends in standardized mortality rates (per 100.000) for causes of death for both sexes at the municipal and department level during the period 1998-2014. These have been calculated from microdata that we obtained from the National Administrative Department of Statistics (DANE). To overcome the problem of under-registration of mortality in Colombia, we applied a method that corrects the total number of deaths by sex, age and cause of death in each municipal area. To test for spatial dependency, we used the global and local spatial autocorrelation indicators Global Moran I and Local Moran I. Results show that in a context of a gradual mortality decline, the corrections we made in the vital statistics considerably improved the quality of the municipal data led to the identification of clusters that had already been previously identified in epidemiological studies which used morbidity registers but did not show up in our preliminary analysis that used the uncorrected mortality statistics. All causes of death show a greater or lesser degree of spatial autocorrelation, although this decreased over time, with the exception of perinatal mortality, ill-defined causes, infectious diseases (women only) and external causes (women only). Moreover, external causes, especially among men, present the most significant levels of spatial autocorrelation and an extension over time to different geographic spaces from the central Andean area to Orinoco and the Amazon rainforest.

Background

The study of mortality is fundamental in understanding the health status of a population and analyzing mortality by cause of death allows one to gain initial insights into possible reasons for mortality differences (Spijker, 2004). Analysing also their spatial distribution and its aetiology (i.e. the causes of the diseases) enables decisions to be made in accordance with the needs of each region, whether in terms of health or other health-related aspects (López & Arce, 2008). Mortality is an indicator of both the health situation and of living conditions, which justifies the need for good information on this phenomenon (Comisión Económica para América Latina y el Caribe, 2006), while health and living conditions are not only related to demographic factors but also to other factors such as social, biological, cultural and political factors.

Interest in the study of mortality in Colombia has increased in recent years due to the changes in the cause-of-death pattern from communicable to chronic diseases. The most studied themes have focused on mortality rates and life expectancy for which updated information is available for at the departmental level. An important emphasis has also been given to external causes, particularly homicide, because of the country's historic specificity and the convergence of problems of a political, economic, moral, legal, psychological and individual nature (Minayo, 1994; Agudelo, 1997). On the other hand, information on the impact of specific causes of death on life expectancy is limited, as well as analyses based on geographical models that allow the identification of mortality clusters. Indeed, geographical analysis of mortality in small areas is a pending subject not only in Colombia but in Latin American demography in general.

Although different contributions have been made to the analysis of cause-specific mortality in Colombia, especially in violent causes (Cendales et al. 2007; Moreno, 2011), there remains a knowledge gap regarding the geographic analysis and life expectancy changes due to large groups of causes at the municipal level. The main contributions on the subject have been made on avoidable mortality, infant mortality, perinatal mortality, dengue (Misnaza et al. 2016; Chaparro-Narváez et al. 2016), analysis of the main causes at the departmental or even municipal level, but are especially descriptive or on the potential years of life lost rather than with the aim of explaining those spatial patterns.

While mortality is transiting from the second to the third phase of the Epidemiological Transition, i.e. a pattern dominated by communicable diseases to one where chronic diseases have become most common (Omran, 1971) , it still has significant rates of both emerging and re-emerging communicable diseases even though chronic diseases are increasing. In the country's interior some departments have different patterns. This is in line with the unequal regional socioeconomic development in the country and consistent with (Frenk et al., 1991) who stated that in Latin American countries the ET is characterized by its dilated and heterogeneous pattern that blends infectious with chronic degenerative and social pathological diseases. This is the main reason why this investigation takes on a geographical perspective that allows identifying clusters of high and low mortality from specific groups of causes of death. To date, there are descriptive analyzes of geographic

data for avoidable causes of mortality in Colombia at the departmental level, but there is no information on a model that helps to understand what variables are involved in the formation of mortality clusters (Instituto Nacional de Salud, 2014).

Spatial analysis – a brief overview

The use of thematic maps and the analysis of spatial distribution, constitute important tools to identify the connection that exists between the phenomena related to health and the territory (Anselin & Cho, 2002). Since the classic association found between the cholera epidemic at the Broad Street water station (London), geographic information systems have made it possible to complement the analysis of data related to human health, as well as in other fields (Croner et al., 1996; Gómez-Barroso et al., 2015).

Much of the geographic information on mortality is related to its statistical distribution (Esteve & Recaño, 2006). However, in recent years, spatial analysis techniques have become more sophisticated as more detailed information has become available related to the geographical location of demographic events. In addition, due to the development of geographic information systems (GIS) and theories associated with territorial structure, we have seen an increase in studies in the social sciences on social, health or economic phenomenon that include space (geographical location) as a determinant variable that affects the variable under study (Anselin, 2010).

Paelinck and Klaassen (1979) introduced spatial econometrics as a discipline in the early 1970s. They identified five characteristics of spatial econometric models: 1) The role of interdependence; 2) asymmetry in spatial relationships; 3) the importance of explanatory factors located in other spaces; 4) nonlinearity or differentiation between ex ante and ex post interaction; and 5) explicit modeling of space. The purpose of spatial econometrics is the analysis of spatial interaction and structure in cross-sectional regression models and or panel data (Anselin, 1988). Spatial analysis is therefore a set of techniques that are used to explore and analyze data by adding value to existing information and allow the models' spatial effects to be verified in terms of their heterogeneity and spatial dependence. The techniques used here for the exploratory analysis of the data is what is called Exploratory Spatial Data Analysis or ESDA, which is characterized by: 1) visualization of spatial distributions; 2) visualization of spatial association; 3) indicators of spatial association (LISA); and 4) multivariate indicators of spatial association. For the analysis of spatial autocorrelation, the coefficient I of Global Morán is the most frequent one. Their values vary between +1 and -1, where the first value indicates perfect positive autocorrelation (perfect concentration), and the second the perfect negative autocorrelation (perfect dispersion); Zero means a totally random spatial pattern. The Global Moran indicator shows the degree of spatial association of a variable for the whole territory, while the Local Morán indicates for each territorial unit, if it is spatially associated to its neighbors. Both indicators use a randomly generated reference distribution and contrast this distribution with the observed distribution; if the probability is high, we accept the null hypothesis, which assumes the random distribution of the values of the variable in the territory and discards the presence of spatial association. For the analysis of these indicators, one must know the

spatial structure of the territorial units of the region under analysis, that is, which units are neighboring which units, these neighborhood relations are obtained from two basic criteria: contiguity and distance (Anselin, 1988).

The literature on the analysis of spatial autocorrelation in issues related to health and mortality is varied and seeks to provide evidence to make public health decisions. It has been used for the analysis of adherence to cancer treatments (Feng et al., 2013) for the analysis of cancer mortality (Kim et al., 2016; Melo, 2010) mortality from cardiovascular diseases, (Roberson et al., 2016; Piuvezam et al., 2015; Gómez-Barroso et al., 2015), maternal and child health (Oliveira, 2013; Rodrigues et al, 2013). The analysis of suicide mortality (Macente & Zandonade, 2012), and the identification of risk areas for communicable diseases (Dos Santos et al., 2016).

Spatial autocorrelation and mortality studies are still scarce in Colombia. Bohórquez and Ceballos (2008), analyzed the information of the homicides recorded in 2001 in a single department of the country, showing that mortality for this cause does not have a random distribution. Regarding spatial patterns Ruíz and Durán (2014) analyzed the infant mortality between 2004 and 2010, showing that there are clear patterns in some departments, while the National Institute of Health (2014) estimated the spatial autocorrelation for avoidable causes of mortality between 1998 and 2011.

Data and methods

Data preparation

For the spatial analysis it was necessary to calculate specific mortality rates by sex, age and cause-of-death for the 1123 municipalities, 4 districts and one capital district (Bogotá) of Colombia. Mortality rates for each major cause were estimated according to the Pan American Health Organization's 6/67 list, from 1998 to 2014 (Table 1). Vital statistics was the source of the information for the numerators, which were directly obtained from the national data file (ANDA) corresponding to non-fetal deaths. The denominators for each municipality were obtained from the DANE population projections for each corresponding year.

It should be mentioned that DANE and other researchers (Rodríguez García, 2007; Vargas & Schmalbach, 2013) have identified important shortcomings in the vital statistics in recent years related to alterations to the mortality register and the turbulent political history and violence Colombia suffered during the last decades and, accordingly, employed similar methods to ours to correct for this at the departmental level. This includes for specific groups of causes. Moreover, in view of this situation, DANE decided to construct mortality tables by sex and department that incorporated significant corrections in infant mortality and other ages based on different internal studies on the coverage of the registry that showed important regional discrepancies. However, these corrections were not passed on at any time to the municipal scale or to the causes.

For this reason, the data we have used in this study come from corrections applied to the obtained aggregate number of deaths in Colombia according to sex, age group, municipality of residence and cause of death. The procedure for estimating the vital statistics we did was as followed:

a) First, we have recalculated the deaths by sex, age group and department of residence for different periods, applying to the denominators obtained from DANE the mortality rates by sex, age group and department of residence, as published by the official DANE mortality tables;

b) Secondly, we have distributed these corrected deaths using coefficients obtained from the Colombian vital statistics microdata, obtaining data for 7 large groups of causes of death according to age, sex and department of residence.

c) Subsequently, data at the departmental level have been redistributed at the municipal level. In this way, we obtain a local series corrected with data by period, sex, age group and cause-of-death categories.

As a way to check the quality of the vital statistics we first calculated life expectancy at different ages at the departmental level (see Map 1 for the names and location of the same) and compared them with official statistics published by DANE, where corrections were made to account for under-registration of mortality. Results (not shown here) revealed that particularly certain areas of Chocó (on the Pacific coast) and Amazon (in the Southeast) were affected by this. To overcome the problem of under-registration of deaths, we therefore applied a method that first corrects the number of age- and sex-specific deaths at the district level. Deaths in each municipality were adjusted accordingly but maintaining the observed municipal cause-of-death structure. As a result of the implemented corrections, a number of high-mortality clusters emerged that the epidemiological literature on Colombia had previously identified using morbidity registers (Ochoa & Osorio, 2006), but which had gone unnoticed in the analysis of vital records (Rodríguez García (2007) identified levels of under-reporting at the departmental level for the year 2000 and are very similar to that we found).

Our next step consisted in calculating the age-, sex- and cause-specific death rates for the major cause-of-death categories for each municipality. In order to minimize yearly random fluctuations we aggregated the data for the following periods: 1998-2000, 2001-2003, 2004-2006, 2007-2009, 2010-2012 and 2013-2014. To allow for comparison over time and across municipalities we used the direct standardization method to calculate Standardaised Death Rates (SDR). This is done by first multiplying age- and sex-specific mortality rates of municipalities by a standard population, taken here as the national population age structure of both sexes combined according to the 2005 census. The population was distributed according to the following age structure: 0, 1-4, 5-9, …, 80+. The open group was chosen to coincide with the lifetables published by DANE. The sum of the products is then divided by the total population of Colombia to obtain the cause-specific SDR for each municipality:

$$SDR^{municipality} = \frac{\sum_{x=0}^{\omega} m_x^{municipality} \times P_x^{COL}}{\sum_{x=0}^{\omega} p^{COL}}$$

Spatial cluster analysis

In order to study the possible existence of spatial dependence in the sex- and cause-specific SDR we used a global and local spatial autocorrelation indicator. It should be noted that spatial statistics is an analytical tool that treats the data of the municipalities as parts of a whole, a territorial structure where neighborhood relations are established and where it is possible to analyze to what extent statistical association exists between the values of a variable that is distributed in the territory. That is why it is necessary, before calculating the indicators, to establish a criterion that clearly determines the municipalities that are neighbors. Based on this criterion, a matrix of weights is constructed that relates each municipality to all others and that serves to calculate the value of the spatial indicator. In the specific context of this work, we use the rook criterion of contiguity to establish neighborhood relations.

In the first case, to measure the existence of global spatial dependence, we used the *Global Moran I* indicator, which is calculated by the formula:

$$\boldsymbol{I} = \frac{\boldsymbol{N} \cdot \sum_{\boldsymbol{i}=1}^{N} \sum_{\boldsymbol{j}=1}^{N} \boldsymbol{w_{ij}} \cdot \left(\boldsymbol{x_i} - \bar{\boldsymbol{x}}\right) \cdot \left(\boldsymbol{x_j} - \bar{\boldsymbol{x}}\right)}{\boldsymbol{S_o} \cdot \sum_{\boldsymbol{i}=1}^{N} \left(\boldsymbol{x_i} - \bar{\boldsymbol{x}}\right)^2} \qquad \boldsymbol{i} \neq \boldsymbol{j}$$

where $\boldsymbol{x}_i$ is the value of the quantitative variable $\boldsymbol{x}$ in zone $\boldsymbol{i}$; $\boldsymbol{x}_j$ is the value of the quantitative variable $\boldsymbol{x}$ in contiguous zone $\boldsymbol{j}$, $\bar{\boldsymbol{x}}$ is the average value of the areas; $\boldsymbol{w_{ij}}$, the matrix weights $\boldsymbol{W}$; $\boldsymbol{N}$ the sample size and $\boldsymbol{S}_0 = \sum_{\boldsymbol{i}} \sum_{\boldsymbol{j}} \boldsymbol{w_{ij}}$, the sum of the weights.

This sole indicator summarizes the overall spatial associations within a territory (here Colombia) according to an analyzed variable. With its calculation a global auto-correlation test can be performed whereby the null hypothesis is that the variable shows spatial independence (i.e. the values of a variable do not depend on those of its neighbors). There are several alternatives to estimate the probability that the distribution of the data is random, but here we will use an approximation to the value of *Global Moran I* from a random permutation (specifically 999 permutations, a methodology that has an associated probability of 0.001).

However, one weakness of the Global Moran I is that it averages out local variations in the level of spatial association. On the other hand, *the Local Moran I* statistic was therefore conceived to be able to identify local patterns of association (hot spots) (Anselin 1995).

Local Moran I is in fact a decomposition of the Global Moran I (*ibid.*) and its mathematical formula is, given an area i:

$$I_i = \frac{z_i}{\sum_i z_i^2 \Big/ N} \sum_{j \in J_i} w_{ij} z_j$$

where z_i is the value of area *i* of the normalized variable and J_i the total of the neighbouring areas *i*. The elements of the weights matrix are, as in the previous indicator, w_{ij}.

The obtained value provides evidence of either

- Local positive spatial auto-correlation, i.e. regions with high values of a variable surrounded similar neighbours (known as hot spots) and regions with low values surrounded by regions who also have low values (known as cold spots); and
- Local negative spatial auto-correlation, i.e. regions with high values of a variable surrounded by neighbours with low values (high-low) and vice versa (low-high).

Thus, positive spatial auto-correlation indicates the presence of clusters of similar values in the territory and is undoubtedly information that will help us to locate the mortality patterns due to similar characteristics throughout the Colombian territory.

Results

Colombia is currently characterized by a decline in mortality levels at regional and municipal levels and shows a certain stability in the territorial pattern in this reduction (see coefficient of variation in Table 3). We do not rule out that the latter result is due to improvements that have been made in the mortality register since 2010 as variance increased during the latter two periods for all causes of death. This is an aspect that we will want to investigate further. However, strong territorial disparities still exist in terms of life expectancy at birth between the different departments (a maximum of 10 years in the case of males and 7 in the case of females; see Table 2). As mortality differences are, by deduction, of greater magnitude between municipalities (Table 3) we performed spatial analysis to ascertain if any spatial dependence can be discerned. We did this for different cause-of-death groupings.

As Table 4 shows, according to the Global Moran indicator in three of the causes analyzed there is statistically significant spatial autocorrelation during all of the years studied in the case of women (cancer, external causes and ill-defined causes). Regarding men, two other causes (infectious diseases and diseases of the circulatory system) as well as total mortality also showed significant spatial association for the whole period. This is despite the overall reduction in mortality and some territorial convergence in the decrease in variation (as indicated by the coefficient). In other words, there is a clear continuity over time in the spatial patterns observed. External causes observed the highest level of spatial association.

Mapping the municipal results allows the identification of mortality hotspots as well as contiguous areas with low levels of mortality (maps 2-9).

All-cause mortality: The general trend for both sexes is a decrease in areas with autocorrelation. The slight break in the trend since 2010 may be related to the spatial variations in the Colombian Vital Statistics registry. The fact that the Global Moran is superior among men can be easily explained by the leading role that men have regarding external causes. As the general level of mortality is the product of different cause-specific trends, the overall pattern conceals many interesting panoramas which include territorial contrasts in the specific causes that we analyzed and are succinctly described below:

Infectious diseases: Different clusters in the Colombian pacific zone, south of the Cauca Valley, north of Nariño, Guajira, the area of Orinoquía (in the east of the country) and Amazonia present high levels of clusterisation. Some of these areas, as well-known by Colombian epidemiologists, are characterized by being jungle, in which there is transmission of diseases such as malaria and where access to drinking water is scarce, as well as areas of health intervention (REF). During the period 2010-2012, there was a rise in malaria mortality in the Eastern part of the Amazon region, which is reflected in a very clear increase in the Global Moran I value for infectious diseases (for men it goes from 0.0650 in 2007-09 to 0.2058 in 2010-2012). The change is also observed in women, but less strong.

Cancer: The Andean zones located in the center of the country have the most aged population. As cancer is a degenerative disease related to having survived to older ages, particularly this area observes the highest levels of clustering of cancer mortality. Moreover, the spatial structure is maintained throughout the study period. The municipalities in blue correspond to areas with low life expectancy where cancer mortality is much lower, in part also due to a lack of diagnosis and almost absence of smoking (Murillo et al., 2004).

Circulatory system diseases: The geographical pattern is very similar here, although the amount of clusterisation is less in the more recent periods. The spatial distribution of these causes is associated with areas that still remain in a less advanced stage of the ET.

Perinatal mortality: Here is a clustering in Orinoquia, Amazonas and certain areas in Pacífico and Nariño, where health services are not accessible to all communities. The municipalities in this part of the country are extensive in territory, what makes access to health care difficult, especially for infants. The spatial autocorrelación among males is higher. A more detailed analysis of the spatial structure showed some recurrence in incomplete coverage in some areas, even after the administered corrections. These problems appear to be related to the health care that municipalities with hospitals provide for outlying (often rural) areas that inadvertently lead to an inflation of death registration of certain urban areas. This assertion, should however, be verified empirically in future.

External causes of death: These are perhaps the most interesting maps as the external causes maintain the highest degree of clustering and continuity in the areas involved. Initially located in Antioquia and Córdoba where armed conflict at different levels (FARC guerrillas, paramilitaries, drug trafficking and illegal mining) overlap throughout the studied period, these areas are maintained during the period and extended to the departments east of the mountain range, to the plain (Meta) and to the southern guerilla area (Caquetá and Putumayo) and later consolidated in Orinoquia and Amazonas. Neither negligible is the mortality linked to urban delinquency, which is of predominantly male character. Also worthy to highlight is the slightly different geography of female mortality from external causes: the Antioquia and Cordoba areas are no longer significant, while municipalities in Meta, Caqueta and Putumayo are also characterized by high levels of mortality from non-natural causes (although no longer during the last period studied (2013-14), except for Meta). The peculiarity of the female trend is explained by the masculinization of the areas where the violence is concentrated.

Remaining natural causes and Ill-defined causes: The results shown by the maps are interesting because they indicate a clustering of under-registration (in red color) located in departments such as Chocó, Cauca, La Guajira and the municipalities in Oriquia and Amazonia. Nevertheless, the decrease in the Global Moran I indicator is good news as this is in line with the improvement that have been made in the quality of vital statistics in Colombia in recent years (Rodríguez García, 2007).

Discussion

The objective of this study was to analyze the possible existence of geographic clusters of mortality in Colombia, their evolution over time and local factors that may explain the geography of mortality from causes in Colombia between 1998 and 2014. Our results based on the spatial indicators and the cartography show that the geographic distribution of causes of death in Colombia has a significant degree of spatial autocorrelation in which male mortality from external causes stands out. Second, the general decrease of all-cause mortality occurs in a context of some stability in the geographical patterns of mortality. Third, in future analyses it would be interesting to perform a more detailed examination of specific causes, in particular, types of tumors, diabetes, homicides and traffic accidents. It is possible that this new strategy will show a higher degree of spatial autocorrelation for some of these causes due to specific territorial patterns. Fourth, the high heterogeneity of the 1123 Colombian municipalities and 5 districts suggests another possible route of investigation, namely the grouping of municipalities into “sub-regions” that are situated between local authorities and departments. This new territorial division would allow the absorption of at least part of the registration errors linked to the regional hospital infrastructure and also raise the statistical and spatial significance of the calculated indicators. Fifth, another future step will be to apply spatial econometric models of an explanatory nature that would test the effect of a wide range of local indicators (e.g. sex ratio, unemployment, housing conditions, access to basic health care). Finally, the application of the ESDA allows the introduction of

a new conceptual element in the analysis of epidemiological transitions, namely geographical space. If we can operationalize this concept, we would have an indicator of "system convergence" that represents changes in cause-of-death patterns. To illustrate, using the results we obtained for Colombia: although there is a gradual reduction of mortality, this occurs without territorial convergence. That is to say, we could have epidemiological transition models with or without territorial convergence, which would add a geographical dimension to the analysis and description of mortality patterns.

Table 1: Cause-of-death classification according to the OPS-WHO 6/67 list

Cause	Code CIE-10
Infectious diseases	(A00-B99, G00-G03, J00-J22, P35.0)
Neoplasms (tumors)	(C00-D48)
Circulatory system diseases	(I00-I99)
Perinatal mortality	(P00-P29, P35.1-P96)
External causes	(V01-Y89)
All other causes	(D50-D89, E00-E90, F00-F99, G04-G98, H00-H95, J30-J98, K00-K92, L00-L98, M00-M98,
Ill-defined causes	(R00-R99)

Table 2. Life expectancy at birth in the Colombian departments. 2005 (to do: comparison with LE before corrections made to data)

Departamento	Hombres	Mujeres	Diferencia
Bogotá	73,81	79,30	5,49
Atlántico	71,84	77,58	5,74
Sucre	71,68	76,87	5,19
San Andrés	71,34	77,03	5,69
Bolívar	71,28	76,37	5,09
Boyacá	71,01	76,72	5,71
Magdalena	70,86	75,71	4,85
Santander	70,77	77,17	6,40
Cundinamarca	70,70	77,00	6,30
La Guajira	70,70	77,31	6,61
Córdoba	70,37	75,88	5,51
Nariño	70,34	75,98	5,64
Colombia	70,20	77,11	6,91
Huila	69,51	75,16	5,65
César	69,36	75,48	6,12
Quindío	69,32	75,87	6,55
Antioquia	69,26	76,83	7,57
Valle del Cauca	68,49	77,66	9,17
Tolima	68,33	75,40	7,07
Caldas	67,70	76,79	9,09
Norte de Santander	67,70	75,51	7,81
Cauca	67,36	73,92	6,56
Putumayo	66,85	74,82	7,97
Risaralda	66,80	76,47	9,67
Meta	66,51	74,34	7,83
Casanare	65,23	72,20	6,97
Arauca	64,80	72,96	8,16
Grupo Amazonía	64,07	74,46	10,39
Caquetá	63,58	72,45	8,87
Chocó	63,07	71,93	8,86

Source: DANE (2007). Estimación de la mortalidad. Conciliación Censal.

Note: The Amazon group refers to the departments of the Amazon, Guainía, Guaviare, Vichada.

Table 3: Descriptive statistics of sex- and cause-specific standardized death rates per population of 100,000. Colombian municipalities (1998-2014).

		Men					
		Period					
		1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2014
All-cause mortality	Mean	637,6	613,9	566,0	508,0	466,8	539,7
	Median	588,4	574,4	527,3	468,4	406,1	505,7
	Coeff. of variation (%)	56,0%	53,2%	52,1%	54,5%	66,2%	47,8%
Infectious diseases	Mean	35,6	31,7	28,6	23,1	21,4	28,3
	Median	22,7	19,8	18,0	13,3	9,4	21,0
	Coeff. of variation (%)	129,2%	132,4%	129,4%	150,6%	233,6%	127,9%
Neoplasm	Mean	67,3	64,1	61,5	59,5	52,7	72,9
	Median	61,3	58,2	56,2	54,3	45,5	68,5
	Coeff. of variation (%)	78,8%	75,3%	71,3%	76,4%	81,3%	64,4%
Circulatory system	Mean	165,5	156,4	157,5	146,2	139,4	162,9
	Median	154,4	149,5	146,3	133,8	124,0	150,8
	Coeff. of variation (%)	66,3%	62,0%	62,0%	65,1%	68,2%	64,1%
Perinatal	Mean	20,5	17,6	16,2	14,5	12,6	18,5
	Median	8,8	5,3	3,7	0,0	0,0	0,0
	Coeff. of variation (%)	165,2%	187,6%	181,4%	213,6%	265,7%	176,8%
External causes	Mean	229,4	230,4	195,8	158,2	134,7	123,9
	Median	193,0	195,8	163,3	136,1	112,1	105,7
	Coeff. of variation (%)	77,4%	77,4%	77,2%	70,1%	76,2%	71,2%
Other causes	Mean	96,4	96,0	91,9	90,5	87,7	115,0
	Median	81,1	80,9	74,7	72,7	64,0	102,6
	Coeff. of variation (%)	82,4%	79,9%	85,7%	84,6%	113,4%	68,3%
Ill-defined causes	Mean	22,9	17,7	14,6	16,0	18,3	18,2
	Median	10,6	8,1	7,2	9,5	11,5	8,1
	Coeff. of variation (%)	165,8%	169,8%	169,9%	149,9%	135,6%	174,4%
		Women					
		Period					
All-cause mortality	Mean	406,7	364,0	334,5	296,6	272,5	335,0
	Median	379,1	337,3	304,9	261,0	223,1	311,6
	Coeff. of variation (%)	58,8%	56,7%	62,8%	60,6%	80,8%	50,6%
Infectious diseases	Mean	29,0	23,8	21,2	16,1	16,0	20,5
	Median	19,3	15,5	12,6	8,8	5,3	13,6
	Coeff. of variation (%)	138,9%	126,9%	165,7%	145,0%	563,6%	148,8%
Neoplasm	Mean	63,4	56,6	53,9	47,1	41,8	55,5
	Median	58,1	52,9	50,5	41,6	34,7	50,3
	Coeff. of variation (%)	74,9%	72,3%	72,9%	74,5%	87,7%	69,5%
Circulatory system	Mean	146,3	131,2	127,6	110,5	100,8	118,1
	Median	138,7	123,8	117,5	99,2	88,4	110,2
	Coeff. of variation (%)	65,4%	62,8%	83,6%	65,0%	71,1%	61,6%
Perinatal	Mean	14,9	12,5	11,3	9,9	8,7	14,1
	Median	4,2	0,0	0,0	0,0	0,0	0,0
	Coeff. of variation (%)	173,5%	195,5%	244,6%	219,2%	273,7%	201,2%
External causes	Mean	43,3	44,1	34,9	30,5	26,3	23,3
	Median	34,5	34,0	27,3	24,6	18,7	17,4
	Coeff. of variation (%)	97,8%	96,8%	94,9%	99,4%	115,4%	108,7%
Other causes	Mean	87,8	81,1	74,6	70,7	65,6	90,6
	Median	75,1	67,7	61,4	56,5	49,8	79,7
	Coeff. of variation (%)	81,6%	80,4%	83,8%	83,4%	97,9%	69,6%
Ill-defined causes	Mean	22,0	14,8	11,1	11,8	13,4	12,9
	Median	9,0	5,0	4,9	5,4	7,0	5,1
	Coeff. of variation (%)	169,2%	185,5%	168,8%	157,1%	165,7%	175,4%

Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE

Table 4: Global Moran I according to period and cause of death. Colombia (1998-2014)

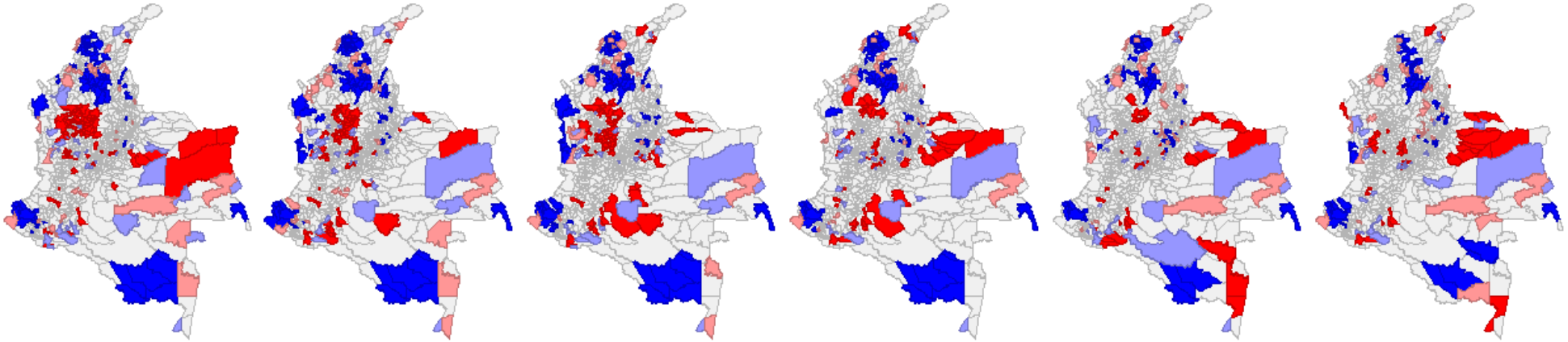
	Hombres					
	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2014
All causes	**0.1916***	**0.2091***	**0.1473***	**0.1155***	**0.0758***	**0.1160***
Infectious diseases	0.1333*	0.1101*	0.0433*	0.0650*	0.2058*	0.0948*
Neoplasms (cancer)	0.1490*	0.1748*	0.1350*	0.1084*	0.0902*	0.1288*
Circulatory system diseases	0.1130*	0.1881*	0.1708*	0.1266*	0.0967*	0.1212*
Perinatal mortality	0.0200	0.0285	0.0313	0.0602*	0.0606*	0.0343
External causes	0.4077*	0.4306*	0.4443*	0.4044*	0.3568*	0.3191*
Remaining causes	0.1081*	0.0586*	0.0113	0.0101	-0.0009	0.0619*
Ill-defined causes	0.1315*	0.1260*	0.2247*	0.1168*	0.1797*	0.1041*
	Mujeres					
	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2014
All causes	**0.1367***	**0.0585***	**0.0140**	**0.0494***	**0.0471***	**0.0945***
Infectious diseases	0.1251*	0.0595*	0.0165	0.0348	0.0837*	0.0814*
Neoplasms (cancer)	0.1708*	0.1584*	0.1220*	0.1354*	0.1202*	0.1341*
Circulatory system diseases	0.1473*	0.1327*	0.0132	0.1019*	0.0428*	0.0866*
Perinatal mortality	0.0208	0.0197	0.0162	0.0583*	0.0340	0.0696*
External causes	0.2267*	0.2633*	0.1983*	0.1505*	0.1263*	0.0875*
Remaining causes	0.1748*	0.0198	0.0095	0.0056	0.0195	0.0535*
Ill-defined causes	0.2055*	0.0876*	0.0886*	0.1882*	0.1643*	0.0574*

Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE. Note: * = significant at $p<0.01$.

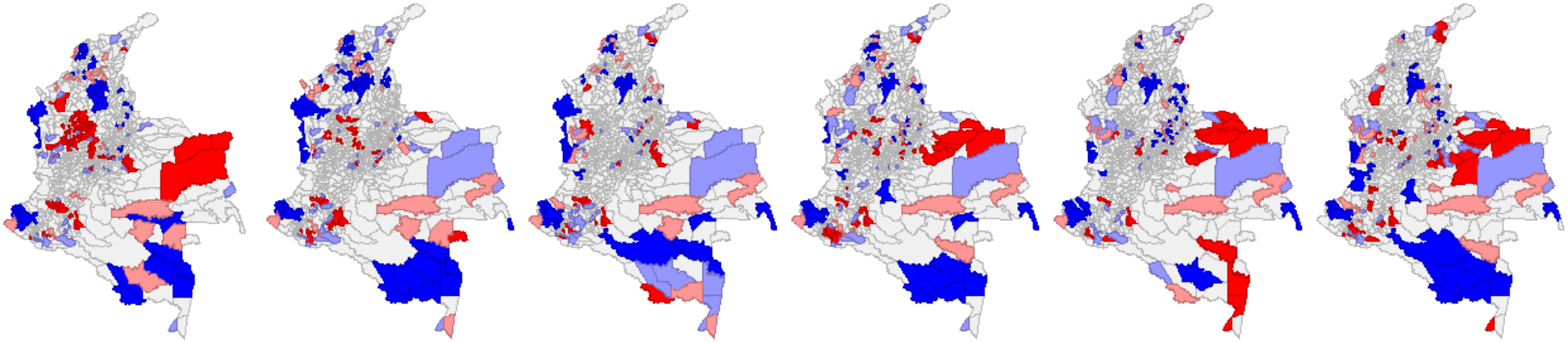
Map 1. Departments and capital district of Colombia

Map 2: Municipal clusters. All-cause mortality. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



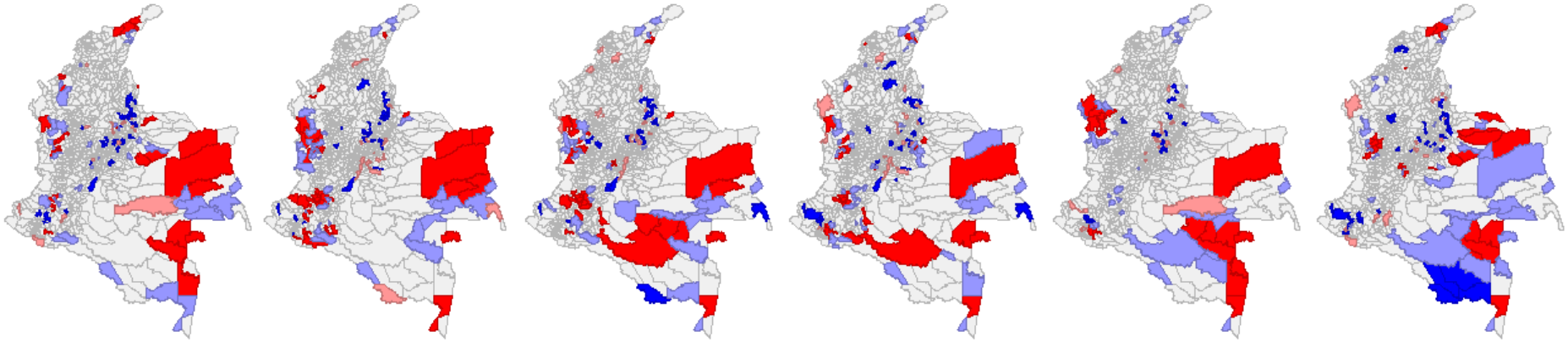
b. Women.



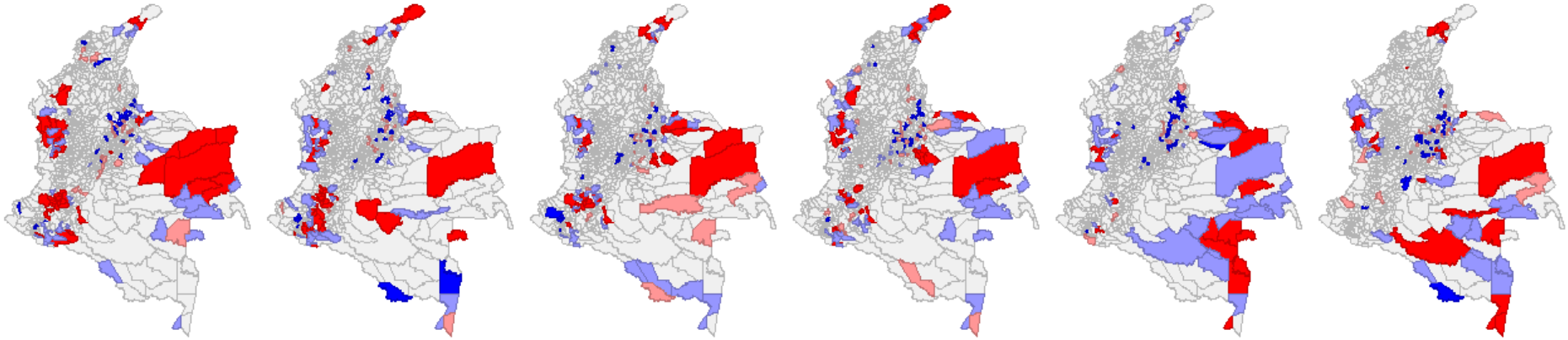
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

Map 3: Municipal clusters. Mortality from infectious diseases. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



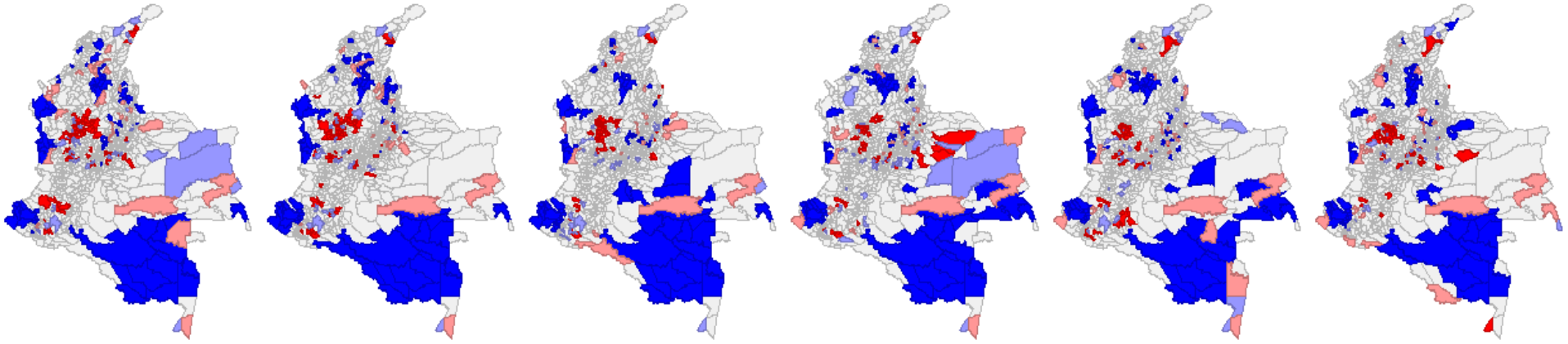
b. Women.



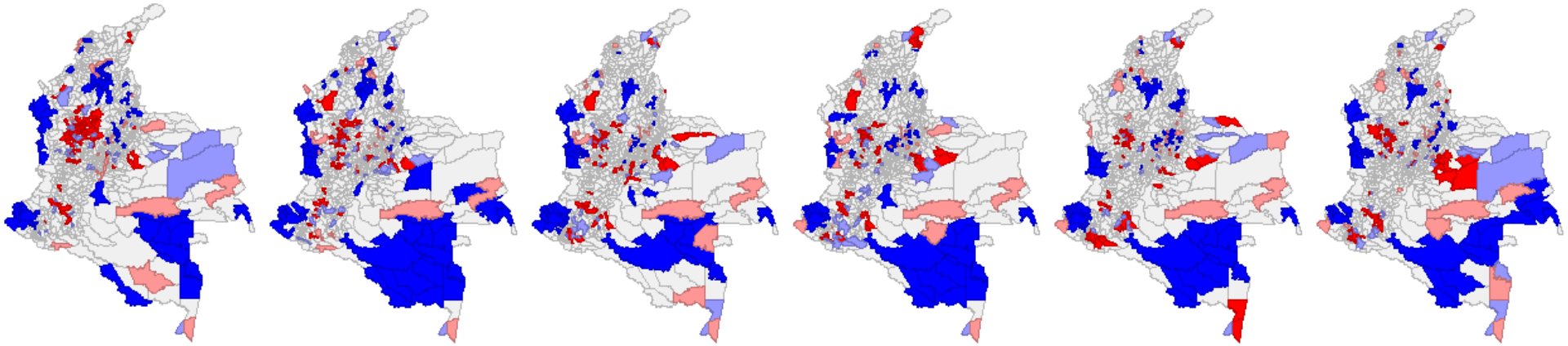
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

Map 4: Municipal clusters. Neoplasm mortality. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



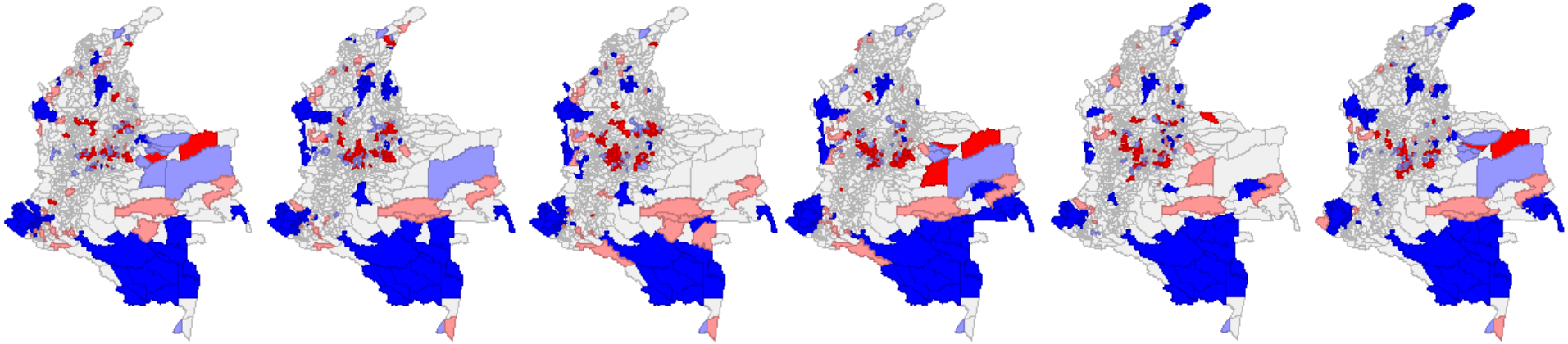
b. Women.



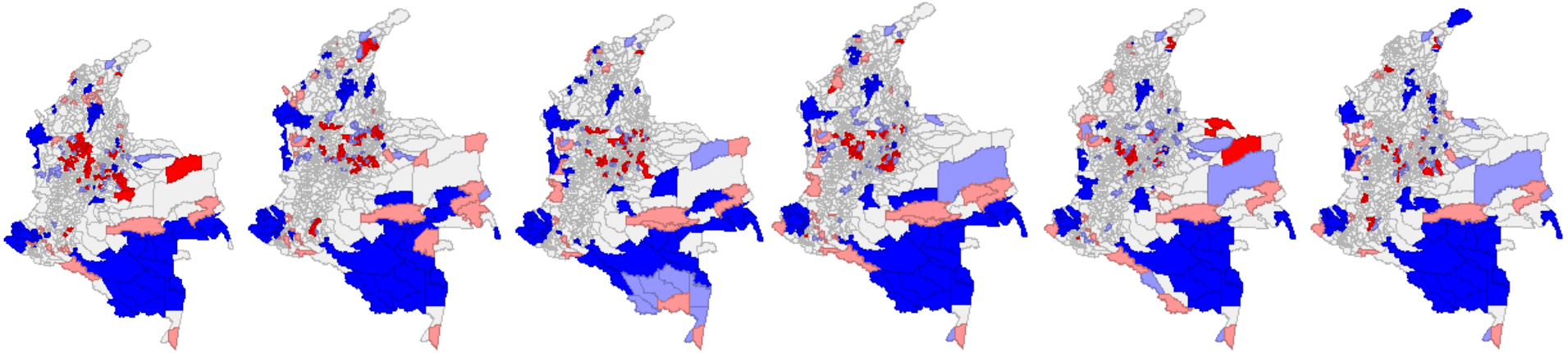
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE

Map 5: Municipal clusters. Mortality from circulatory system diseases. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



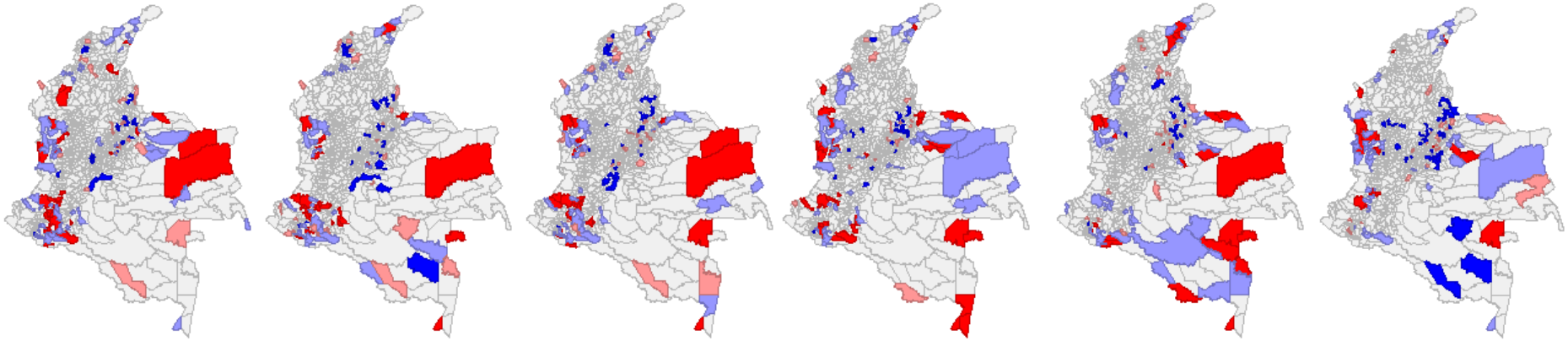
b. Women.



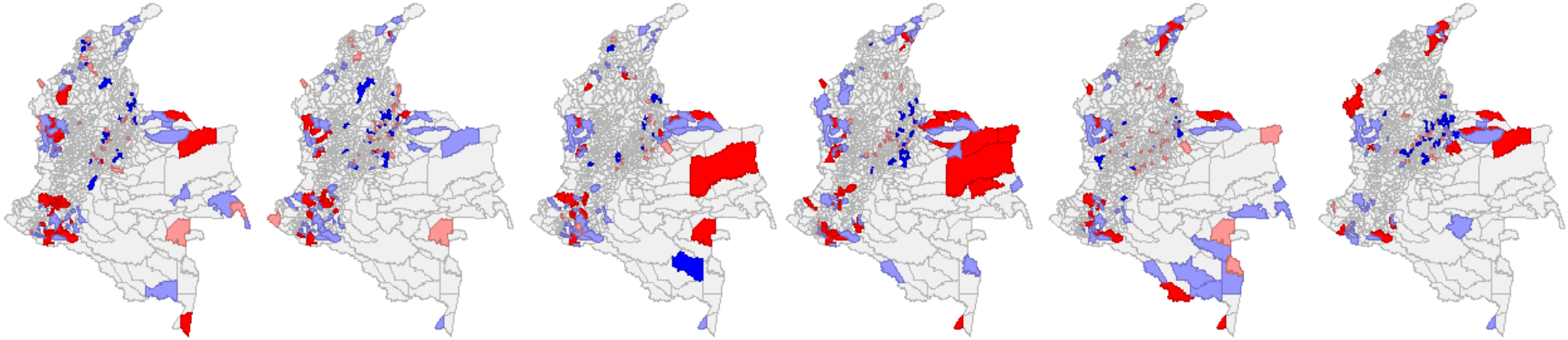
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

Map 6: Municipal clusters. Perinatal mortality. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



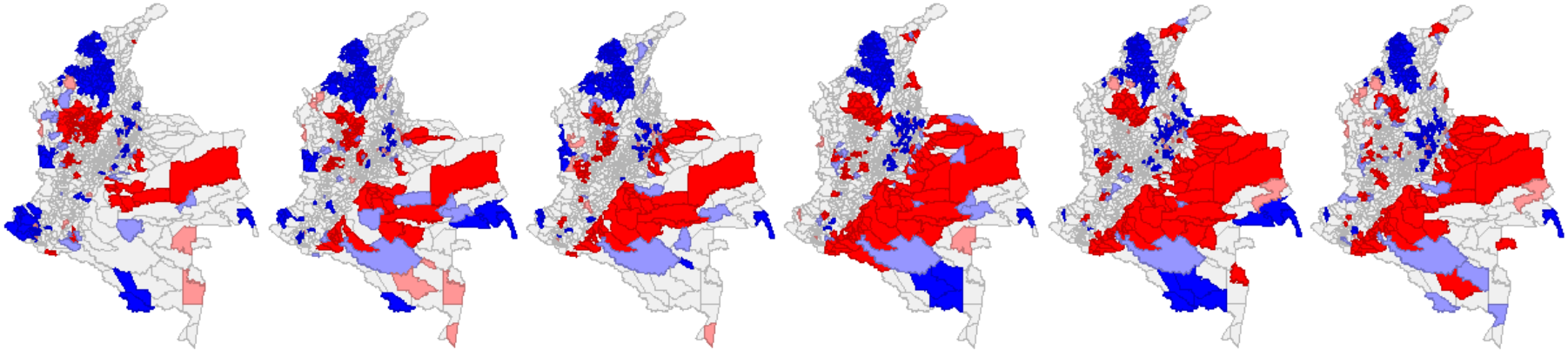
b. Women.



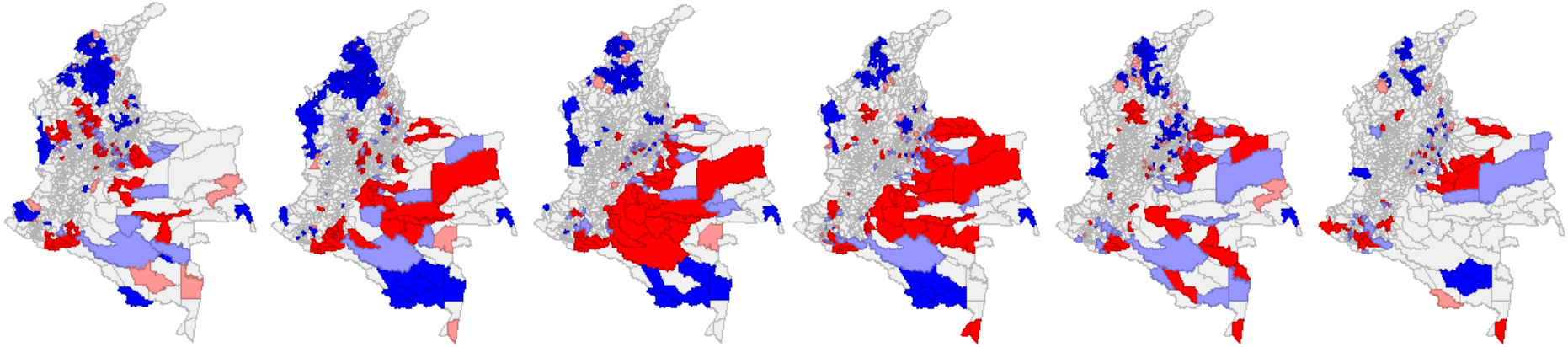
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

Map 7: Municipal clusters. Mortality from external causes. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



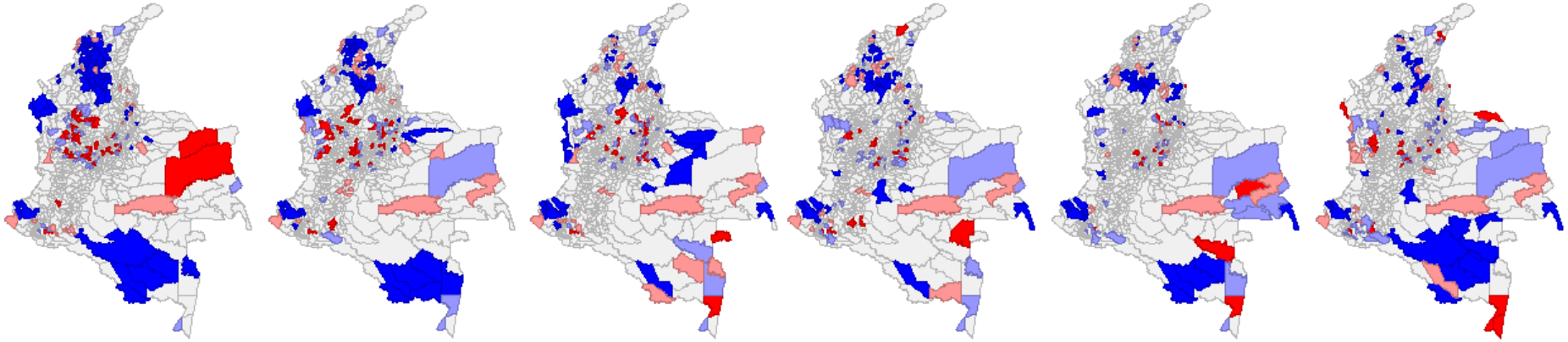
b. Women.



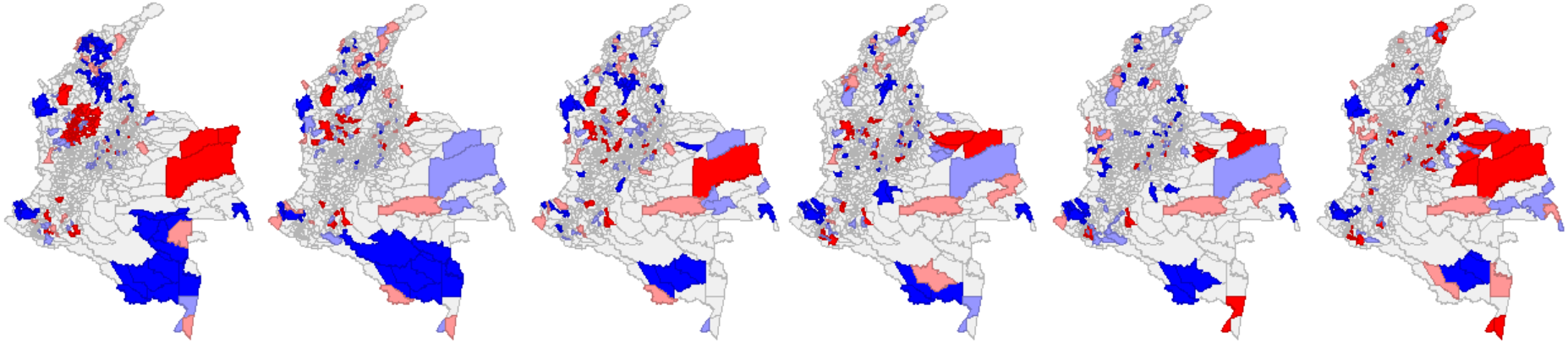
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

Map 8: Municipal clusters. Mortality from other causes of death. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



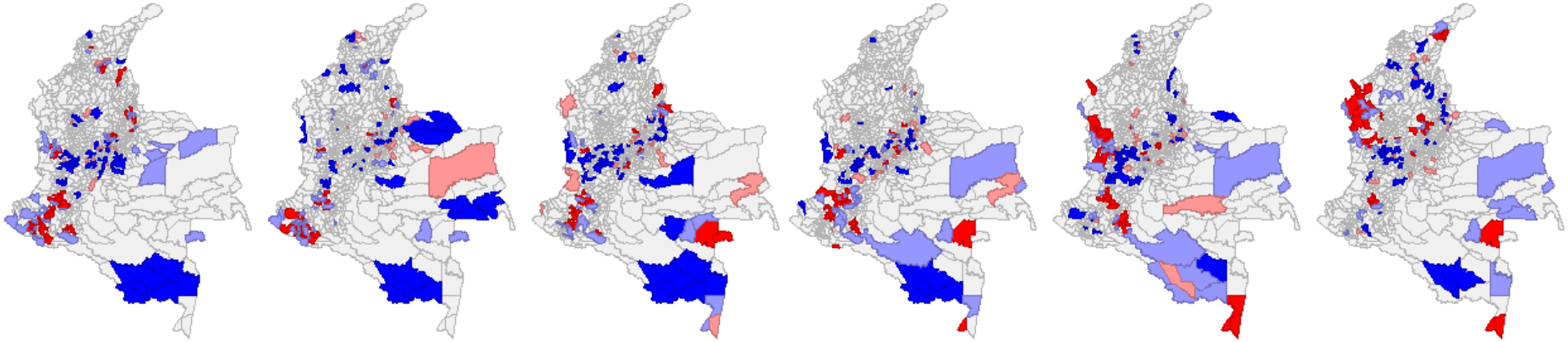
b. Women.



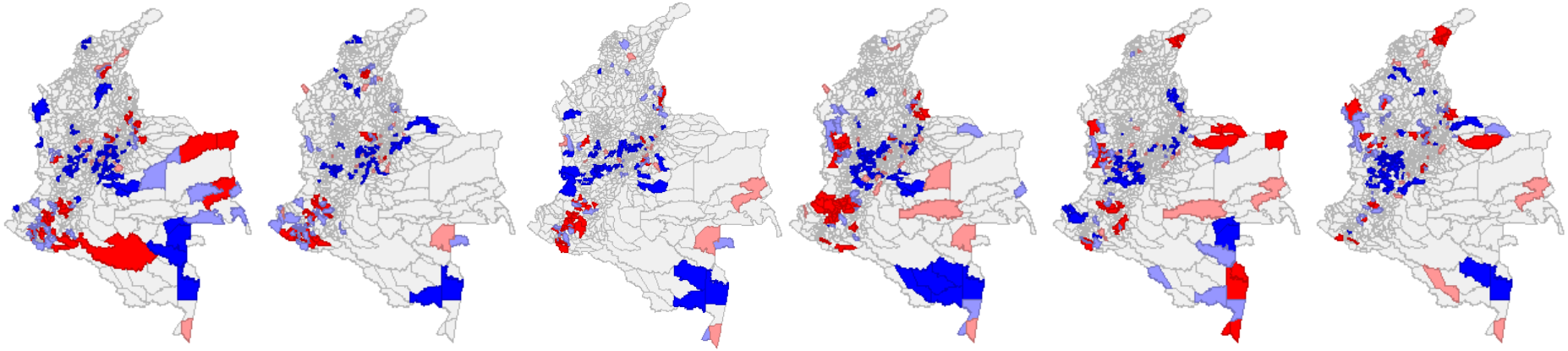
Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

Map 9: Municipal clusters. Mortality from ill-defined causes. Colombia (1998-2014).

a. Men. 1998-2000 2001-2003 2004-2006 2007-2009 2010-2012 2013-2014



b. Women.



Source: Own calculations based on the micro data obtained from Vital Statistics and the denominators supplied by DANE.

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