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The spatial heterogeneity of factors of feminicide: The case of Antioquia-Colombia

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ABSTRACT

In Latin America, homicide is a leading cause of death among women. The aim of this paper is to examine the spatial heterogeneity of factors influencing feminicide in Antioquia, Colombia. This article adds the impact of drug trafficking location on feminicide to the existing research. Classic models assume that the parameters of these factors are spatially distributed in a constant manner. However, this assumption has been frequently challenged due to the systematic differences of feminicide occurring within different geographical units, giving rise to the presence of spatial heterogeneity. In this article, geographically weighted Poisson regression (GWPR) is used to explore the spatial heterogeneity in these data relationships. Feminicide in the Department of Antioquia, Colombia, is studied using a range of classic explanatory factors. The results show that, in addition to the classic factors, coca-producing areas in Antioquia are directly related to number of feminicides. The findings also show that relationships in feminicide data are better presented by GWPR than by the classic model.

1. Introduction

According to the World Health Organization (2012), violence against women is a major public health problem and a violation of human rights, and femicide, or the killing of women, is the most extreme form of violence against women. It should be noted that the prevalence of lifetime domestic violence in Latin America is 70%, indicating that violence against women has reached epidemic proportions (Alhabib, Nur, & Jones, 2010). Moreover, several Latin American organizations have warned about increasing homicidal violence against women, what is known as "femicide" or "feminicide,"[1] and the failure to implement necessary controls and prevention measures. A generic definition of the term "femicide" was first used by Diana Russell (Russell, 1982) and has had some relevance in Latin America where a great deal of studies and discussions have been carried out on the conceptualization. Regardless of its denomination, according to Grana (2001), "the reality [is] that femicide exists and is a problem." It is important to pay timely attention to this phenomenon and combat female homicides, since public policies to tackle these problems have been ineffective. Indeed, the impunity for victimizers still remains. The nature of feminicide has been addressed in different contexts (Widyono, 2008), such as armed conflicts, robbery and gangs, although one of the most studied types is intimate partner femicide (IPF) (Russell, 2008), as an extreme case of intimate partner violence (IPV) (Campbell, Webster, & Glass, 2009).

Few studies have been carried out on the phenomenon of feminicide, most of which deal with this issue from a theoretical point of view. In addition, these studies usually focus on gender inequality as the single most important factor in the murder of women, thus playing down the importance of other significant factors that have a role in feminicide. As the Convention of Belem do Para, Brazil (Organization of American States, 1994) sets out, states must take account of the vulnerability of women to violence for reasons such as race or ethnicity, their status as migrants, refugees or displaced persons, as well as

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[1] The question of whether to use the term "femicide" or "feminicide" is a cause of debate. Although they are related, the concept of feminicide builds on the term femicide and therefore should not be used interchangeably. Specifically, femicide is defined as the "the killing of females by males because they are female" (Russell, 2008), while feminicide "encompasses more than femicide because it holds responsible not only the male perpetrators but also the state and judicial structures that normalize misogyny" (Sanford, 2008). In this paper, we will use the term "feminicide" except when specifically citing sources that use the term "femicide."

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women who are subject to violence while pregnant and those who are disabled, under-age, elderly, socioeconomically disadvantaged or affected by situations of armed conflict or deprived of their freedom.

Feminicide has been studied from many different angles, including the social perspective, criminology, health, law, ethics and others. Space is a crucial question in the study of feminicide (Brickell & Maddrell, 2016; Córdoba, 2010, pp. 95–120; Flores & Sparks, 2017; Fragoso & Cervera Gómez, 2013, pp. 1–23; Fuentes & Hernández, 2013; Martin & Carvajal, 2016; Schatz, 2017), thus justifying a study on this phenomenon from a geographical perspective. Agnew (2015) highlighted the lack of quantitative works that examine feminicide and in particular its relationship with drugs from a geographical point of view, and called for a more quantitative approach to studying feminicides as an outcome of territoriality and drug trafficking. Moreover, the author describes some quantitative works in the literature that question the relationship between feminicide and free trade as superficially convincing. This underlines the need to analyze the spatial distribution of factors that affect feminicide from a quantitative and geographical approach, particularly the effects of drug trafficking. Some of the risk factors for feminicide reported in the literature are socioeconomic status, foreign country of birth, education, younger age, drug, poverty, war, and social disorganization, among others. Due to the spatial dependence of these factors, it is important to use the appropriate spatial statistical methods based specifically on a geographical approach. Therefore, in this paper we use spatial quantitative methods to examine some of the main factors traditionally studied in the literature, especially the literature on coca production.

Feminicide is a socio-demographic phenomenon which might behave similarly in nearby geographic units, but which may develop differently in different areas of a region of interest, thus leading to spatial effects, particularly spatial autocorrelation and spatial heterogeneity (Baller, Anselin, Messner, Deane, & Hawkins, 2001). According to Anselin (1988), spatial heterogeneity could be due to varying coefficients or non-constant variances. We are interested in the first case because it is likely that the effects of factors which influence feminicide are not the same across the Department of Antioquia. This aspect is important because the effect of variables over feminicide varies in space.

Given that feminicide is a major problem that requires an urgent solution in Antioquia, it is necessary to clarify the intensity and spatial patterns of the occurrence and development of the phenomenon, understand its determinants and identify the places that are most affected by it. In doing so, we aim to contribute to policy efforts to prevent and eradicate feminicide by increasing the tranquility and confidence of the people of the municipalities of Antioquia and, most importantly, reduce the human toll, especially among young people who are the main victims of this violence.

One of the first questions that researchers and activists must address is how to detect spatial patterns of feminicide in different settings and contexts, what kinds of interventions are most effective in preventing feminicide, and how to measure their effectiveness (Widyono, 2008). These issues have given rise to our main research question, which is to determine if the effect of the factors influencing feminicide is constant or variable for each municipality and the social implications that this may have.

To answer this research question, three objectives are proposed: 1) to model and analyze spatial variations of the common factors driving feminicide and the effect of coca production using geographically weighted Poisson regression (GWPR); 2) to compare the estimated performance of a generalized linear model (GLM), in which the factor effects are considered to be constant, to the GWPR estimation, in which the factor effects are considered spatial variables; and 3) to provide specific results for the factors related to violence against women that can be of use to governments in making decisions to prevent this phenomenon. To achieve these objectives, geographic information systems (GIS) and spatial analysis techniques have been used.

The remainder of this paper is organized as follows. The recent literature on feminicide is reviewed in section 2. A description of the methodology used for the analysis is provided in section 3, while the study area, data and variables are described in section 4. In section 5, the results are presented and GWPR and GLM are compared. This is followed by a discussion of the results and their social implications in section 6. Finally, conclusions are drawn and future lines of research are proposed in section 7.

2. Literature review

Russell (1982) originally defined femicide as "the killing of women because they are women." In a similar manner, the National Institute of Legal and Forensic Sciences (INMLCF, 2014, by its Spanish acronym) and the recent Rosa Elvira Cely Law (2015) of Colombia define feminicide as "the death of women because they are women, [it] is the most extreme expression of violence against women." Feminicide is one end of the continuum of violence intended to reproduce the subordination of women in the social order (Bejarano Celaya, 2014). The perpetrators can be intimate partners (husbands, lovers, etc.), acquaintances or strangers who belong to criminal organizations or not. Feminicide has been studied in different contexts (Beyer, Layde, Hamberger, & Laud, 2014; Pinchevsky & Wright, 2012), including sexual violence (Coy, Kelly, Foord, & Bowstead, 2011; Fragoso, 2002; Olivera, 2006) and dowry-related deaths (Bhalotra, Chakravarty, & Gulesci, 2016; Carlson-Whitley, 1993; Stone & James, 1995), among others. A variety of sources are used to collect data on feminicide (police, hospitals, courts, etc.), which have been aggregated into different spatial units. The largest number of cases of feminicide in Latin America have occurred in Ciudad Juarez, Mexico (Fragoso, 2002; Schatz, 2017); Guatemala; Mar del Plata, Argentina (Fregoso & Bejarano, 2009); Honduras (Menjívar & Walsh, 2017) and El Salvador (Walsh & Menjívar, 2016), although Colombia also has a high prevalence of feminicide (Carmona López, Gómez Caballero, & Castro Rodríguez, 2013).

2.1. Explanatory factors

From a social perspective, three theories have been developed to explain marital violence: social stratification, inequality and social disorganization (Straus, 1994). The theory of social disorganization seeks to explain engagement in prohibited behavior in social groups (Frye & Wilt, 2001) and has been traditionally used to explain homicide rates and feminicide (Sampson & Groves, 1989). In recent years, researchers have been concerned with introducing novel structural factors in homicide studies (McCall, Land, & Parker, 2010). Risk factors for feminicide include race, socioeconomic status and foreign country of birth (Beyer et al., 2014; Frye et al., 2008), and are a reflection of the intersection of the main axes of social domination (Grosfoguel, Oso, & Christou, 2015). However, other factors, such as education, younger age, drug use, geography or poverty, also play a role. Pinchevsky and Wright (2012) conducted a systematic review of studies on the factors explaining IPV.

A low educational level has been found to be a risk factor for feminicide (Campbell et al., 2003), that is, education has a positive effect against violence and homicide (Ingram & Marchesini da Costa, 2015). According to O'Campo et al. (1995), demographic variables, such as partner's education could be equally or more important than the characteristics of the woman in explaining violence. This and other authors (Beyer et al., 2014; Brewer & Smith, 1995; Browning, 2002) also highlight the importance of victims' age in feminicide.

Poverty and economic inequality are significantly associated with homicide (Baron, Straus, & Strauss, 1988; Brewer & Smith, 1995; Grana, 2001). Poverty can be measured using different variables. Loftin and Hill (1974) argued that poverty is one of the most important determinants of homicide. To measure poverty, the authors use a poverty index based on infant mortality, education, households with lower incomes and other variables. However, it is likely that these variables are related, which causes a problem of multicollinearity. Land, McCall, and Cohen (1990) and D'Antonio-Del Rio, Doucet, and Chauvin (2010) studied homicide rates in cities, and showed that it is better to use an index when the empirical estimates of structural variables exhibit instability due to high levels of collinearity among several regressors. Differentiating the effect of each of these variables independently remains an ongoing problem 20 years later (McCall et al., 2010).

Drug markets and violence are inextricably linked (Friman, 2009; Schatz, 2017), thus suggesting that drug use could also be related to feminicide (Campbell et al., 2003; Russell, 2008). In Ciudad Juarez, Mexico, for instance, there exists a relationship between violence and the cartels that control the production and distribution of drugs, and drug-related murders and feminicide must be understood in relation to gendered violence (Campbell, 2010; Wright, 2011). In a similar line, Agnew (2015) argued that the changing geographies of the global drug trade have been associated with feminicide in Ciudad Juarez since 1993 and that "the 'balloon effect' of drug trafficking flows provides a more convincing rationale for understanding these homicides" (Agnew, 2015, p. 428). In Colombia, feminicide is linked to arms trafficking, the production and distribution of drugs, and guerrillas. All these variables are very closely interrelated and with violence against women, which can be used as spoils of war (Richani, 2013). In this regard, Segato (2006) considers that feminicide is a transformation of gender violence "linked to new forms of war." Indeed, feminicide has been used as a military or paramilitary strategy to perpetuate social control through terror (Sánchez, 2014).

Women who live in environments marked by social disorganization could be at a greater risk of homicide (Grana, 2001). Social structures affect criminal opportunity by influencing the socioeconomic factors of places and individuals' routine patterns of activity, which are directly affected by their environment (Cahill & Mulligan, 2007). In a neighborhood context, the proximity between locations may lead to a higher concentration of crime rates or victimization (Wilcox, Land, & Hunt, 2003). As Pinchevsky and Wright (2012) indicated, at the core of social disorganization theory, the characteristics of the neighborhood where an individual lives are important for understanding IPV. The spatial dependence of some or all the explanatory variables highlights the need for appropriate statistical methods suited to these circumstances.

3. Methodology

The main methodology used in this paper for modeling feminicide has been based on the use of a GWR model. For the purpose of comparison, Poisson regression was initially used followed by an extension of it called GWPR. The following is a short explanation of these methods.

When the conventional regression (OLS) assumptions (normality and constant variance) are not met, GLM emerges as an alternative method to include non-normal responses, such as Poisson regression. GLM has three components: a random component, a systematic component and a link component. A GLM requirement of the random component is the dependent variable belonging to the exponential family. It is easy to see that the Poisson distribution belongs to this family (Dobson & Barnett, 2008).

The global model that was used for this study is as follows:

$$\ln[E(y_i)] = \beta_0 + \beta_1 \ln(P_i) + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + \varepsilon_i \quad (1)$$

where, $\ln[E(y_i)]$ is the natural log of the expected number of feminicides per municipality in the study period, P_i is the offset variable, which was the size of the i-th population at risk, x_{ji} is the j-th explanatory variable, β_j is the j-th model parameter and ε_i is the i-th random error term.

If we know the value of the geographical coordinates of the observations, equation (1) can be rewritten by the geographically weighted Poisson model as:

$$y_i \sim Poisson\left[P_i \exp\left(\sum_k \beta_k(u_i, v_i)x_{ki}\right)\right] \quad (2)$$

where u_i and v_i are the geographical coordinates of the i-th observation. In this study, these were the centroid coordinates of each of the municipalities of Antioquia. Under this model, if the estimated parameters vary spatially, they can be viewed on a map (Mennis, 2013).

The estimation of the parameters is determined by a diagonal spatial weights matrix $\mathbf{W}(u_i, v_i)$ of size $n \times n$ whose main diagonal is formed by the weights of the observations. This square matrix is conditioned upon the location and therefore changes in each of the points. The parameters of the model are given by the expression:

$$\hat{\boldsymbol{\beta}}(u_i, v_i) = [\mathbf{X}^T\mathbf{W}(u_i, v_i)\mathbf{X}]^{-1}\mathbf{X}^T\mathbf{W}(u_i, v_i)\mathbf{Y} \quad (3)$$

For an observation i, observations that are closer will have greater weight than those that are farther from observation i; therefore, they will have a greater effect on the estimated parameters and the weights of the array will be larger as the distance becomes smaller (Leung, Mei, & Zhang, 2000). The influence of observations around observation i is given by the weighting function or Kernel (w_{ij}). Two functions are commonly used: the Gaussian function and the bi-square function, given respectively by:

$$w_{ij} = \exp\left[-\frac{1}{2}\left(\frac{d_{ij}}{b}\right)^2\right] \quad (4)$$

$$w_{ij} = \begin{cases} \left[1 - \left(\frac{d_{ij}}{b}\right)^2\right] & \text{if } d_{ij} < b \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

where d_{ij} denotes the distance between observations i and j and b is the bandwidth. The bandwidth may be constant, as in function (4), (fixed kernel) or may be variable, like function (5), (adaptive kernel) (Fotheringham, Brunsdon, & Charlton, 2003).

In addition to the importance of the spatial weighting function, it is also paramount to select the optimum bandwidth, b. To do so, three selection criteria can be used: cross-validation (Cleveland, 1979), the traditional Akaike information criteria (AIC) and the corrected Akaike information criteria (AICc) (Hurvich, Simonoff, & Tsai, 1998; Nakaya, Fotheringham, Brunsdon, & Charlton, 2005). The measures used to compare the performance of the GLM and GWPR models were (Li, Wang, Liu, Bigham, & Ragland, 2013): AICc, the mean absolute deviation (MAD) and the mean squared error (MSE). The last two statistics are measures of how close a fitted model is to the data and are given by:

$$MAD = \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)}{n} \quad (6)$$

$$MSE = \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n} \quad (7)$$

where y_i is the number of feminicides observed in municipality i, $\hat{y}_i$ is the predicted number of feminicides in municipality i and n is the number of municipalities in Antioquia. The model with the lowest value in these measures indicates that the setting is better. Additionally, the local deviation percentage explained by the geographically weighted model (Local_pdev) was used, which is equivalent to the local R-squared value (local determination coefficient) and allows visualizing the spatial variation of the explanatory power of the model (Nakaya, 2014). The higher the value is, the better the fit of the data.

In this work we have also analyzed the spatial autocorrelation of variables. A variable has a spatial autocorrelation effect when the values observed in a municipality depend on the values observed in neighboring municipalities. We used Moran's index (Moran, 1950) to analyze the presence of spatial autocorrelation. This varies between −1 and 1, where a positive (negative) value indicates positive (negative) spatial association. To estimate the models and determine the different

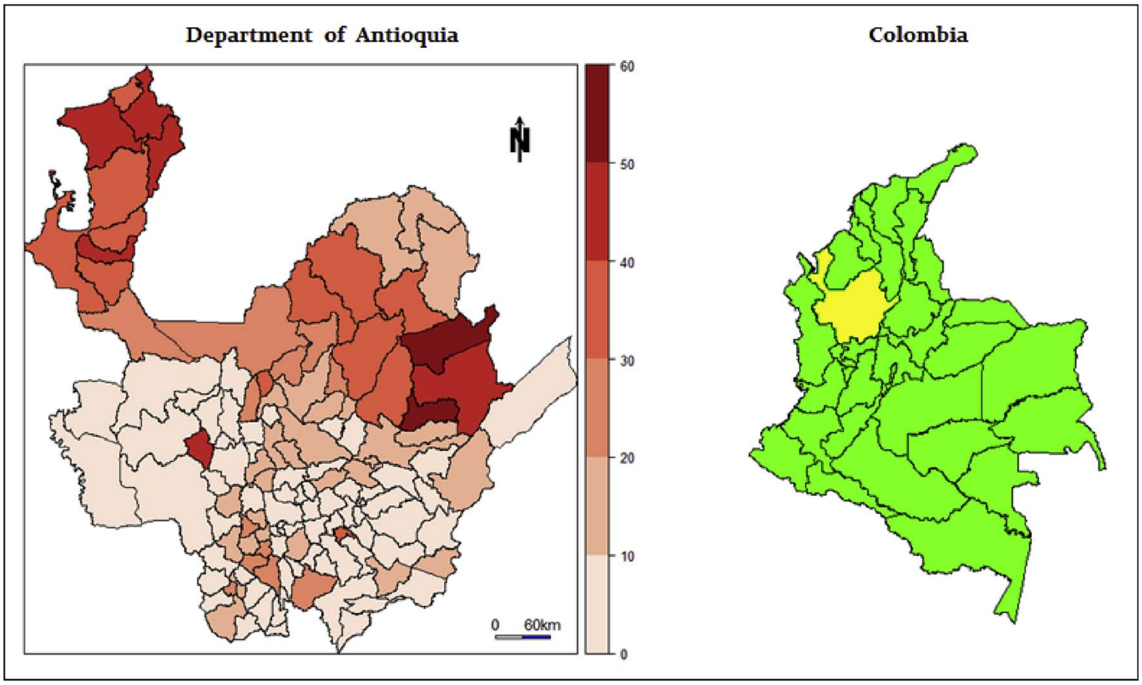

Fig. 1. Spatial distribution of number of feminicides in the Department of Antioquia (left) and location of the Department of Antioquia in Colombia (right).

measures, GWR4 and R software (Team R Core, 2013, library spgwr) were used.

4. Study area, data and variables

The study area was the Department of Antioquia located in northwest Colombia (South America) (Fig. 1). The department spans an area of 63,600 km^2 with a total population of 6,500,000 inhabitants. Antioquia is divided into 125 municipalities and has its capital at Medellin, where half the population of the department lives.

Our aim is to analyze and model feminicide in Antioquia. This site was selected because of its very vulnerable social conditions, which are mainly due to the fact that the department has one of the highest gender murder rates (INMLCF, 2014), as well as a high level of forced displacement, which contrasts with its favorable economic conditions (income, employment and poverty, etc.).

Antioquia is the department that has been most affected by the armed conflict in terms of the number of forced displacements (Victim and Witness Support Unit, UARIV, 2013, by its Spanish acronym). According to INMLCF (2014), Antioquia has the third highest percentage (11.3%) of feminicides in Colombia, which is only surpassed by Valle del Cauca and Cundinamarca. However, this contrasts with the fact that Antioquia is the country's second largest department and among those with the highest per capita income, with poverty rates below the Colombian average. It is also one of the departments with the highest percentage of people employed in manufacturing, and stands out for its textile, metallurgy and mining and transport industries (National Administrative Department of Statistics, DANE, 2016, by its Spanish acronym), in addition to coffee production. It has a very low percentage of indigenous peoples and a somewhat larger Afro-Colombian population.

In order to determine the existence of feminicide individual data that reflect the real nature or cause of the murder are required (Agnew, 2015). However, this type of information is not always available and, where appropriate, data aggregated by municipalities can be used. When working with aggregate data, such as the total number of victims or the rate of victims per municipality, such data are considered an adequate measure of the degree of violence against women (Frye & Wilt, 2001; Ingram & Marchesini da Costa, 2015).

In 2012, the Vienna Declaration on Femicide in the United Nations proposed a definition of feminicide as:

The killing of women and girls because of their gender, which can take the form of, inter alia: 1) the murder of women as a result of domestic violence/intimate partner violence; 2) the torture and misogynist slaying of women; 3) killing of women and girls in the name of "honour"; 4) targeted killing of women and girls in the context of armed conflict; 5) dowry-related killings of women and girls; 6) killing of women and girls because of their sexual orientation and gender identity; 7) the killing of aboriginal and indigenous women and girls because of their gender; 8) female infanticide and gender-based sex selection foeticide; 9) genital mutilation related femicide; 10) accusations of witchcraft and 11) other femicides connected with gangs, organized crime, drug dealers, human trafficking, and the proliferation of small arms (Laurent, Platzer, & Idomir, 2013, p. 4, p. 4).

In this work, the response variable (*Feminicide*) captures the number of female homicides due to different causes, the main ones of which are related to gender violence (family abuse, sex crimes, gangs, armed conflicts, vendettas, robberies, hanging, strangulation, poisoning, violence towards marginal groups, suffocation, etc.). The response variable can be considered a proxy of the concept of feminicide as defined in the Vienna Declaration, since a strong relationship is expected between the number of murders of women due to the indicated causes and the concept of feminicide as defined in the Declaration. This variable has been observed in each of the 125 municipalities of Antioquia in the period 2012–2013. For this study, the specific characteristics of each municipality are used as predictor variables, some of which have been employed in previous studies mentioned in the literature review (section 2.1) that explain this phenomenon.

The explanatory variables of the model are presented below. These variables capture the main factors reported in the literature and are included in the Convention of Belem do Para, Brazil (Organization of American States, 1994).

As mentioned, feminicide is the extreme form of intimate partner violence, with 38.6% of female homicides perpetrated by an intimate partner (Messing, Campbell, & Snider, 2017; Stöckl et al., 2013). Therefore, it is expected that there will be a strong and direct relationship between the number of women murdered and the variable rate of domestic violence (*Partner Violence*). Similarly, according to the INMLCF (2014), 1508 women in Colombia were victims of sexual violence every month in 2012, of which one was also murdered. According to the Inter-American Commission on Human Rights (IACHR, 2013), it is common for women to have postmortem signs of sexualized abuse and torture (Menjívar & Walsh, 2017). Therefore, a positive relationship between the rate of sexually assaulted women (*Sexual Woman*) and the number of murders of women is also expected. Moreover, it is expected that immigration, social exclusion and segregation, captured by the rate of forced displacements in each of the municipalities (*ForcedDis*), will be directly related to feminicide since the politics of exclusion colludes with a localized "culture of control" to fuel violence against women (Nudelman, Boira, Tsomaia, Balica, & Tabagua, 2017; Shalhoub-Kervorkian & Daher-Nashif, 2013). In line with previous research, the rate of children under 18 years of age (*Age*) could also be positively related with feminicide (Beyer et al., 2014; Brewer & Smith, 1995). Another variable directly related to feminicide is the rate of adolescent pregnant women (*Pregnant*), which represents women's state of vulnerability (Li, Kirby, Sigler, Hwang, LaGory, & Goldenberg, 2010; Pengpid, Peltzer, McFarlane, & Puckpinyo, 2016). On the other hand, a high educational level is a protective factor of feminicide (WHO, 2012) and is associated with a low level of homicides (Brewer & Smith, 1995), while a low level of education is associated with a large number of women who suffer violent deaths (Castaneda Salgado, 2016). Hence, there is likely to be an inverse relationship between feminicide and the net school coverage rate (*School*). Other variables that may be related to feminicide are housing and poverty (Castaneda Salgado, 2016). Thus, precarious housing and greater economic dependence is expected to be more directly related to feminicide (Grana, 2001). This paper used an index representing the proportion of households with unmet basic needs (*UBN*). In order to calculate the index, the following indicators were used: inadequate housing, homes critically overcrowded, housing with inadequate services, households with high economic dependence and households with school-age children not attending school. We have used an index because it is not always easy to differentiate the effect of each of these variables independently due to problems of multicollinearity (D'Antonio-Del Rio et al., 2010). The presence of drug trafficking has also been shown to be linked to feminicide (Castaneda Salgado, 2016; Martin & Carvajal, 2016; Schatz, 2017). In particular, we explore the effects on feminicide of the proportion of area dedicated to coca production (*Coca*) in each of the municipalities of Antioquia. In 2012, paramilitary and drug trafficking groups were responsible for 21.9% of sexual attacks against women in Colombia (INMLCF). Thus, we expect feminicide in Antioquia to be directly related to the cultivation of coca.

Databases of violence-feminicide (*Feminicide*), sexual crime rates (*Sexual Woman*) and intrafamily violence rates (*Partner Violence*) were provided by the INMLCF (2012–2013), regional northwest-Medellin, Antioquia, for the years 2012 and 2013. The population forecast, the proportion of households with *UBN*, the rate of children under 18 years of age (*Age*) and the number of young adolescent pregnancies (*Pregnant*) for the municipalities of Antioquia were supplied by DANE. Data on the rate of displacements due to violence (*ForcedDis*) and net school coverage rate (*School*) in each of the municipalities were provided by the Secretary of Health and Education of the Government of Antioquia (2012–2013), while data on the proportion of area covered by coca (*Coca*) was provided by the National Police – Anti-Narcotics Directorate (2013).

5. Results

Table 1 shows the descriptive statistics of the variables. As shown in Fig. 1, there were 10 feminicides on average per municipality during the study period, although their spatial distribution is heterogeneous. As can be observed, there are spatial clusters formed by municipalities with similar values, with the extreme northwest and northeast of the department showing a higher frequency of feminicides. Fig. 2 shows the spatial distribution of the explanatory variables. The rate of children under 18 years of age (*Age*) and the rate of intrafamily violence (*Partner Violence*) show a strong dispersion, although the variable with the highest coefficient of variation (CV) is the proportion of area dedicated to coca cultivation. Fig. 2 also reveals the presence of clusters in the spatial distribution of each of the explanatory variables. As can be seen, the municipalities with the highest concentration of coca production coincide with municipalities with the highest number of feminicides.

Table 1
Descriptive statistics of the variables.

Variable	Min	Max	Mean	SD	CV
Feminicide	0.00	59.00	9.65	24.47	2.54
School	25.21	87.45	75.92	14.90	0.20
ForcedDis	8.45	57.23	34.26	7.76	0.23
UBN	5.43	64.87	37.98	19.09	0.50
Age	0.00	61.34	7.70	11.55	1.50
Pregnant	3.07	56.87	36.76	18.87	0.51
Coca	0.00	3.38	0.07	0.35	5.00
Sexual Woman	0.00	98.76	76.96	53.75	0.70
Partner Violence	0.00	75.54	25.45	35.86	1.41

To capture the spatial relationship between the number of feminicides and the factors that influence this phenomenon, GLM and GWPR were used. Before using GWPR, however, it is advisable to analyze the presence of spatial autocorrelation. Table 2 shows the Moran's I with their respective *p*-values for all the variables. Moran's I is a measure that expresses the intensity of the relationship between the values of the variable with respect to the values of the same variable in neighboring municipalities. From these results, it is concluded that all variables have a statistically significant spatial autocorrelation. Moreover, the largest variance inflation factor (VIF) value among all independent variables was 2.126 (*Pregnant*), which suggested that there is no risk of high multicollinearity.

The GLM method was used to model the relationship between the number of feminicides and the explanatory variables. The results of the final model are shown in Table 3. All variables have a statistically significant coefficient and their signs were as expected. Schooling (*School*) has a negative bearing on feminicide, indicating that with an increasing school coverage rate, the number of feminicides decreases in each municipality. By contrast, the impact of the other variables on the phenomenon is positive, that is, when the value of these variables increases, the number of feminicides also increases.

As stated above, GWPR has the ability to capture and examine the non-stationarity of the data hidden by the global models (GLM). This tool allows obtaining coefficients whose values change spatially, thus permitting a different set of coefficients to be obtained for each of the points that form the test sample. We have used the adaptive kernel so that the GWR model adapts better to the spatial irregularities of Antioquia, while the AICc method implemented in GWR4 was used to select the bandwidth. To summarize the estimation of the parameters under GWPR, three statistical values for each variable are shown in Table 3: minimum, median, and maximum. The median of the local regression of coefficients showed a positive and negative impact on feminicide. The range of variation of all the variables maintains the sign, except for the variable *ForcedDis*, whose sign changes (i.e., −0.2842, 0.5990).

5.1. Residual analysis and local fit of the GWPR

The analysis of the residuals of the geographical pattern indicates no spatial autocorrelation (Fig. 3a). The figure for GWPR Local_pdev (see Fig. 3b) shows the spatial variation of the explanatory power of the model. As can be seen, the municipalities showing the best fit or which best explain feminicide are located in the east and north of Antioquia,

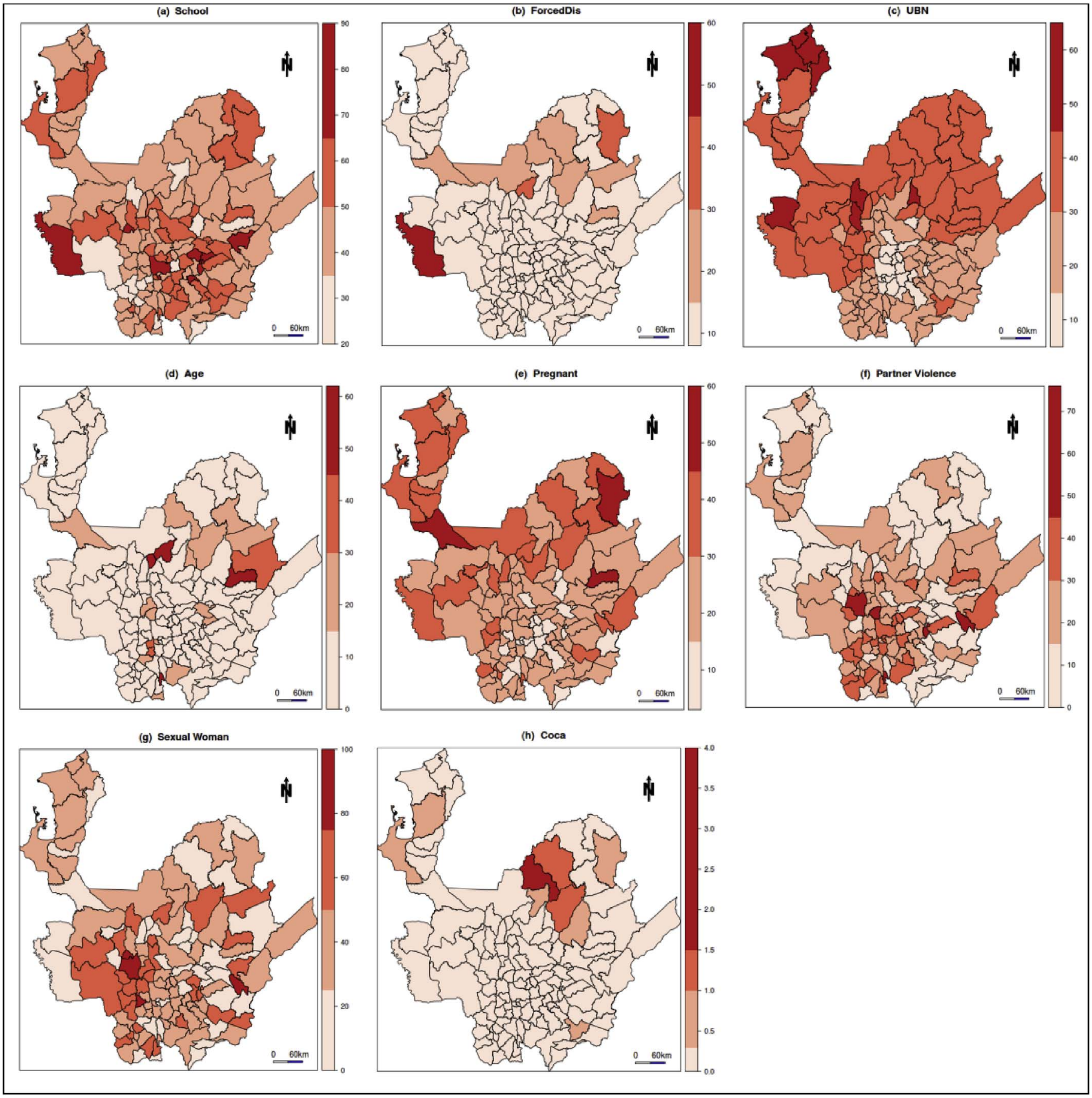

Fig. 2. Spatial distribution of the explanatory variables in the model.

Table 2
Moran's I statistics for the explanatory variables.

Variable	Moran's I	Z-score	p-value
School	0.1570	2.6470	0.0090
ForcedDis	0.4005	8.1708	0.0000
UNB	0.5889	9.7135	0.0000
Age	0.1848	3.0152	0.0010
Pregnant	0.3769	7.2127	0.0000
Coca	0.4542	8.5073	0.0002
Sexual Woman	0.3748	6.9735	0.0001
Partner Violence	0.5045	8.6332	0.0000

which are the areas with the greatest number of feminicides.

As stated above, one of the differences between the two models is that the coefficients in a global model are assumed to be constant throughout the study area, while they vary geographically in a local model. Moreover, according to the results of the local and global modeling, the parameters initially estimated in both models were consistent with their signs, as expected. The residual analysis of both models also yields better results in the GWPR than in the Poisson regression (GLM). This good result is checked statistically with the values shown in Table 3. According to the Moran's I statistics, the global model presents spatial dependence in the residuals, thus violating the assumption of no correlation of residuals (Leung et al. (2000), while the residual from the estimated parameters of GWPR shows spatial independence.

Table 3
Results of the GLM and GWPR models.

Dependent variable number of feminicides	GLM	GWPR		
Independent variables		Min.	Median	Max.
Intercept	−4.3560**	−6.0398	−5.4230	−4.7983
School	−0.2501**	−0.2992	−0.0101	−0.0008
ForcedDis	0.3211**	−0.2842	0.1692	0.5990
UNB	0.2898**	0.0239	0.2735	0.5902
Age	0.4439**	0.0990	0.3098	0.7001
Pregnant	0.0429**	0.0002	0.0207	0.0596
Coca	2.6704**	0.0056	1.9823	2.5902
Sexual Woman	3.8746**	0.0012	2.8731	5.8242
Partner Violence	4.0824**	0.0023	2.0324	5.7834
Moran´s I	0.1986*	0.0560		
MAD	2.0352	1.0234		
MSE	6.1203	4.3827		
AICc	277	152		

**Regression coefficients are statistically significant at the 0.001 level.
*Moran's I is statistically significant at the 0.01 level.

The goodness-of-fit measures that were obtained for the two models are shown in Table 3. The three measures are found less in the geographically weighted model (Li et al., 2013). This indicates that the GWPR better explains the heterogeneity of the data and provides excellent results for explaining feminicide.

6. Discussion

Undoubtedly, the most important results of the modeling of feminicide are the local coefficients estimated for each of the explanatory variables, since they allow visualizing the spatial variation of these coefficients (see Fig. 4). In what follows, we discuss the results regarding the influence of each of the explanatory variables on feminicide and the social and political implications of this phenomenon.

In Fig. 4a, the negative sign of the coefficients indicates that there is an inverse relationship between the net school coverage rate (*School*) and feminicide. This relationship is in line with the conclusions of the World Health Organization WHO, (2012)), which indicate that higher public spending on education and the elimination of gender inequalities in access to secondary education can contribute to reducing gender violence and feminicide. In addition, we have observed that this relationship is not constant for all the municipalities and that the effect of schooling is higher in the center of the department (where the capital city of Medellin is located) than in the periphery. This finding is of interest since a one unit increase in the school coverage rate results in a higher decrease in the number of feminicides in municipalities located closer to the center of the department than in the peripheral areas. This suggests that it is necessary to invest more in education in the peripheral areas than in the central areas in order to reduce feminicides to the same degree. The National Development Plan of 2014–2018 (DNP, 2013) is expected to improve this situation in coming years.

We expected to find a direct relationship between the rate of displaced persons in each of the municipalities (*ForcedDis*) and feminicide in Antioquia given that Colombia had the highest number of displaced women as a result of the country's internal violence (IDMC, 2014). Moreover, the number displacements in Antioquia reached a high in 2002, since the department's geographical, social and economic conditions attract illegal armed groups. These armed groups, as well as the military, instrumentalize and kill women (Benavides, 2015), what has been called “corporate feminicide” (Incháustegui Romero, 2014). In our work, the results of the estimated coefficients in Fig. 4b show that the sign is mostly positive, especially in the northeast, thus indicating a direct relationship between *ForcedDis* and feminicide, although a change in the sign of the coefficients across the plane can be observed.

Moreover, the municipalities of Antioquia with the highest proportion of households with *UBN* are generally located in the north of the department, with those in the extreme northwest being the most disadvantaged (San Juan de Urabá, San Pedro de Urabá, Arboletes and Necoclí) (Fig. 2c). These municipalities also have a high number of feminicides (Fig. 1). The direct relationship between the rate of households with *UBN* and feminicide is stronger in the peripheral municipalities of Antioquia, both in the north and in some municipalities in the south (Fig. 4c). This relationship between poverty in remote areas and feminicide has been observed in other countries such as Mexico (Flores & Sparks, 2017). The municipalities located in the center of the department have a lower proportion of households with *UBN* as well as a lower number of feminicides, and the relationship between the two variables is weaker. These results coincide with those of Grana (2001), among others, who have shown that women living below the poverty line and those marked by social disorganization are at an increased risk of homicide (Grana, 2001). Although this relationship was evident and expected, this work highlights the need for the authorities of Antioquia to target public policies at specific regions

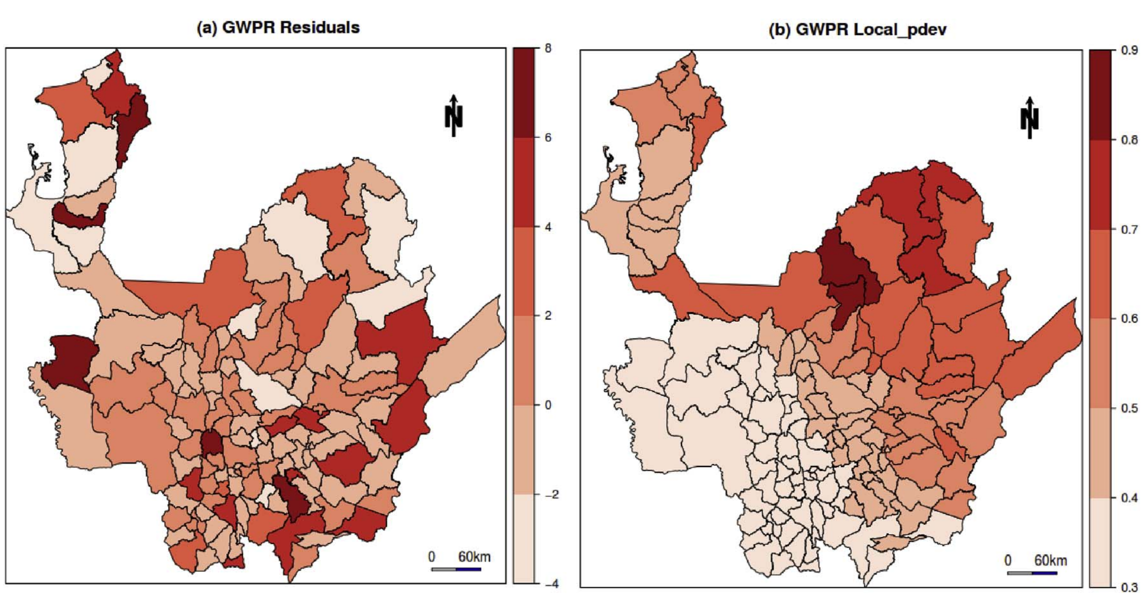

Fig. 3. Residuals and goodness-of-fit (Local_pdev) with GWPR.

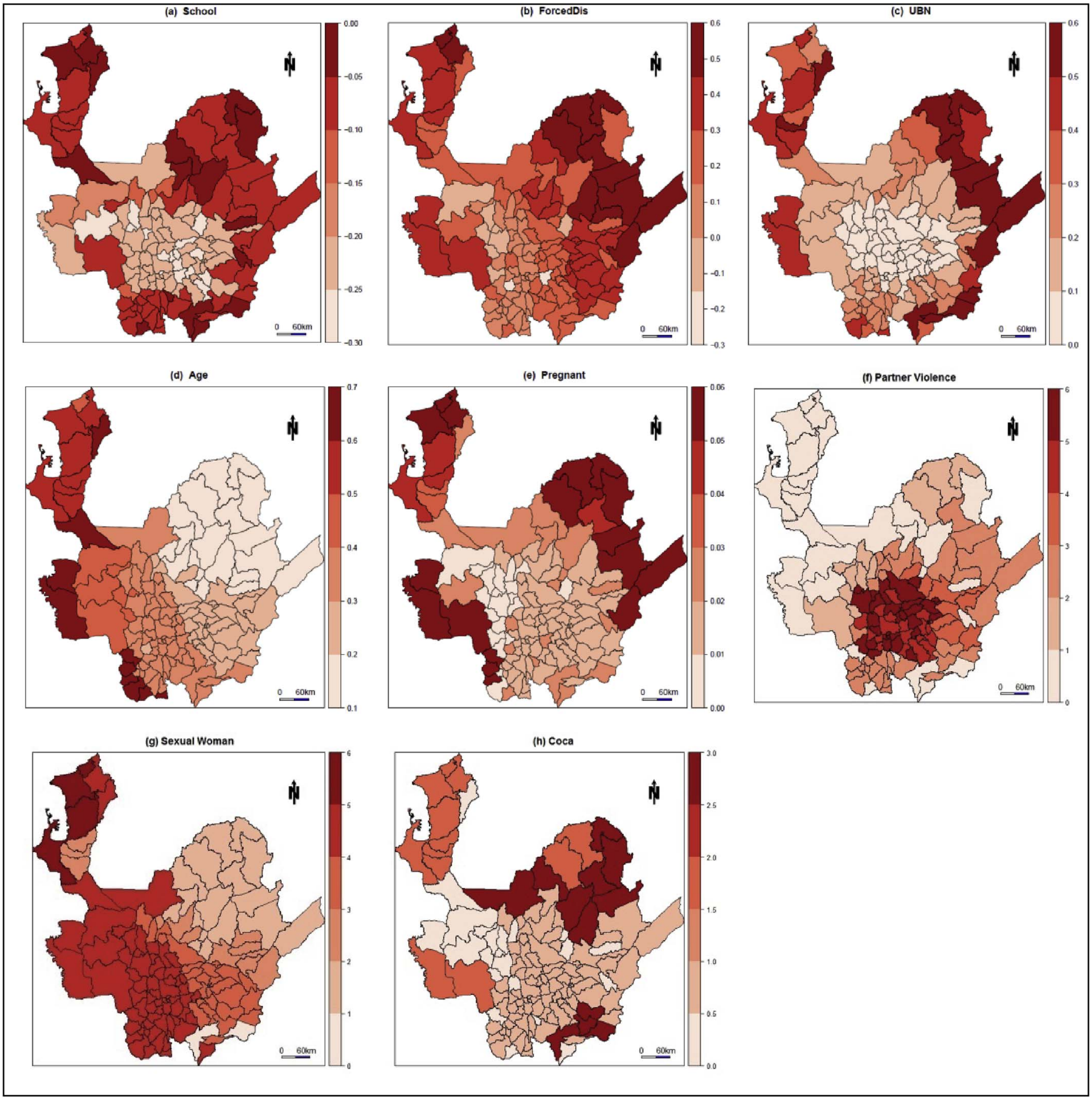

Fig. 4. Local coefficients of each explanatory variable.

in order to improve the quality of life, promote the development of these marginal communities and reduce the high poverty gap, all of which would contribute to structural social changes and hence a decrease in feminicide; a phenomenon which has had a profound effect on the department.

As regards the rate of children under 18 years of age (*Age*), children account for less than 15% of the population in most municipalities of Antioquia. The municipalities with the highest percentage of those under 18 are more concentrated in the center-north and northeast of the department (Fig. 2d), several of which also have high levels of feminicide (Remedios, Vegachi, Toledo and Mutatá). Although the percentage of young people under 18 is not particularly high in the west of Antioquia, the direct influence of the young age of the population exerts a stronger effect on the number of feminicides (Fig. 4d). As we move to the east, however, a gradual decrease in the intensity of the relationship between the two variables can be observed (Fig. 4d), thus suggesting that the high rates of feminicide in Remedios and Vegachi appear to be due to factors other than the percentage of children in the population.

Several studies have found an increased risk of physical violence and gender violence against pregnant adolescents (Covington, Justason, & Wright, 2001; Silverman, Raj, Mucci, & Hathaway, 2001). In Antioquia, more than a third of new mothers aged 15 have been victims of intrafamily violence (Camargo & Pérez, 2016). The municipalities with the highest rates of teen pregnancy (*Pregnant*) are distributed throughout the department, although they seem to be more concentrated in the north (Mutatá, El Bagre and Vegachi) (Fig. 2e); an area which also has the largest number of feminicides. The direct relationship between the two variables is stronger in peripheral areas, specifically in municipalities located in the west, the extreme northwest and the northeast of the department (Fig. 4e), which are also those with the highest rates of teenage pregnancies. By contrast, the relationship between teenage pregnancy rates and feminicide is weaker in the center of the department.

Sexual violence and intrafamily or partner violence are closely related to feminicide; the extreme form of the gender violence continuum (Bejarano Celaya, 2014; Beyer et al., 2014; Coy et al., 2011). In 2012 and 2013, women in Antioquia suffered the highest frequency of different forms of intrafamily violence, accounting for 77.5% and 76.6% of all cases, respectively (Sánchez Zuleta, Montoya Gómez, & Sepúlveda Murillo, 2015). These manifestations of intrafamily violence are the third leading cause of feminicide (INMLCF, 2014). In our work, the rates of intrafamily violence (*Partner Violence*) are unevenly distributed in the municipalities of the department (Fig. 2f), with the highest rates found in Santa Fe de Antioquía, San Jerónimo, Caracolí, Guatapé and Fredonia. The direct relationship between intrafamily violence and feminicide is strongest in the central area of the department and weaker in the northwest (Fig. 4f). The rates of sexual crimes against women (*Sexual Woman*) are also unequally distributed in Antioquia. They appear to be somewhat higher in the municipalities in the center-west of the department, and are particularly high in Santa Fé de Antioquía, Armenia and Caracolí (Fig. 2g). The relationship between the variables *Sexual Woman* and feminicide reveals a clear pattern: it is especially strong in the extreme northwest and the west half of the department, and decreases closer to the northeast (Fig. 4g). Unquestionably, partner violence and sex crimes are two social problems that affect women of different social classes, ethnic groups, ages and educational levels. These problems require prompt and timely attention by the departmental authorities in order to mitigate the deaths of women, increase reporting and punish the perpetrators.

Coca leaf production in Antioquia is not the highest of Colombia. In 2012, there were a total of 2725 hectares of coca plantations, a figure that fell sharply in 2013 (UNODC, 2014a). Coca cultivation (*Coca*) in Antioquia is located in the northeast (especially in Tarazá and to a lesser extent in Cáceres and Anorí), in the extreme northwest (Turbo) and in the municipality of San Francisco (southeast) (Fig. 2h). Numerous illegal armed groups that engage in extortion, illegal mining and principally coca cultivation operate in these areas (Díaz & Torres, 2004). In addition, these areas suffer from forced recruitment, threats, persecution, sexual abuse of women and forced displacement. The influence of coca production on feminicide is straightforward and particularly intense in the northeast and southeast of the department, both of which are neighboring, coca-producing municipalities. By contrast, the relationship is particularly weak in the west central department, which has little or no coca plantations (Fig. 4h). The eradication of drug trafficking and its victims is one of the main recommendations of the Organization for Economic Co-operation and Development (OCDE, 2013, p. 51) for Colombia and a key objective of the 2014–2018 National Development Plan (DNP, 2013, by its Spanish acronym). Coca production has been one of the sources of financing of illegal armed groups in Colombia (DNP, 2013). However, following the signing of the final agreement to put an end to the armed conflict between the government and the FARC-EP in 2016 (Presidency of the Government Republic of Colombia, 2016), coca production for this purpose is expected to end. In addition, in response to this problem, the government has implemented a plan to provide financial incentives to replace coca plants with alternative crops, such as coffee and cacao.

7. Conclusions

Feminicide is a social scourge that undermines the lowest social strata and prevents human development, since it causes deaths that could be avoided (Incháustegui, López, & Echarri, 2012). The data show that feminicide is a crime empowered by social exclusion and the increasing spatial segregation of communities in Antioquia. In summary, the figures for feminicide in Antioquia for the years 2012 and 2013 are particularly high in the extreme northwest and northeast of the department. Feminicide in the north of the department appears to be closely related to coca production (and drug-related violence, we assume), high rates of households with unmet basic needs and teen pregnancy and low (although not the lowest) school coverage rates. In the west, feminicide appears to be related to rates of sexual violence and to a lesser extent to the schooling rate, the rate of households with unmet basic needs and the percentage of children under 18 years of age. In the central area of the department, feminicide seems to be related particularly to intrafamily violence and sexual violence against women. In the northeast of Antioquia, feminicide again appears to be more closely related to coca cultivation, unmet basic needs, teenage pregnancy and the school coverage rate, while in the southeast area it is related to coca production, rates of households with unmet basic needs and the schooling rate. Without doubt, these results can contribute to policy decisions aimed at controlling and preventing this phenomenon affecting the development and economic growth of a country.

In this article, we have explored a number of explanatory variables or factors of feminicide in Antioquia, Colombia. To this end, we implemented a geographically weighted regression model, particularly a geographically weighted Poisson regression, to capture the spatial non-stationary relationship between feminicide and inherent characteristics of the municipalities of Antioquia. A GLM was calibrated with a GWPR model. The latter yielded better results for explaining feminicide, thus indicating that all the estimated parameters show a pattern of spatial variation and permitting us to draw real conclusions for each municipality. In addition, the maps in Fig. 4 show the municipalities in which feminicide is more or less sensitive to variations in each of the explanatory variables. In general, the results suggest that the department of Antioquia has marked differences not only in terms of its population, but also with regard to its educational, social, cultural and political systems. A spatial relationship between the response variable and the explanatory variables was clearly observed, as well as how the explanatory variables behave differently in the department. In line with the literature, the type of influence (direct or inverse) of the explanatory variables was as expected.

GIS and spatial methods can aid not only in determining where feminicide occurs, but also the social change that many researchers in the field seek to contribute to (Coy et al., 2011). Moreover, it is well known that there are systematic differences across geographical areas in regional studies and conventional statistical tools are therefore not appropriate to explain this spatial heterogeneity.

Based on the results of this research, we propose some policy recommendations for combating feminicide. These include investments to improve education (WHO, 2013), the reduction of economic poverty of women (López-Pons, 2011) and the implementation of programs that are not limited to intimate partner or intrafamily violence, but take into account the complexity of violence against women in territories where forced displacement and the reintegration of paramilitaries and ex-combatants have taken place or in areas where drug production and trafficking (or the war against drug trafficking) are associated with high levels of homicides (UNODC, 2014b). In this sense, it is necessary to advance in the analysis of the relationship between coca production and feminicide from a geographical perspective.

This study is framed in empirical studies that demonstrate, from a spatial approach, the relationship between feminicide and its main associated factors, considering the political and social implications of this phenomenon. This study also contributes to a geographical vision of feminicide through the implementation of spatial statistics tools that highlight the regions to which efforts must be directed. Future research should be aimed at using other statistical tools that include the spatio-temporal dimension and exploring other factors that are expected to be related to feminicide, such as the degree of impunity in this type of crime (Incháustegui Romero, 2014).

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