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Research Paper

Relationship analysis between the spread of COVID-19 and the multidimensional poverty index in the city of Manizales, Colombia

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A B S T R A C T

COVID-19 has forced government and health agencies to take measures to mitigate the spread of the disease and thus safeguard as many lives as possible. These measures have initially impacted the economy of many countries, and therefore they have been forced to gradually return to a new normalcy, in what they have called reopening. For reopening policies to be effective, it is necessary that the people in charge of drawing up these policies know the local behavior of the propagation of COVID-19, and beyond this they can understand that between the cases of COVID-19 and the socioeconomic conditions of their population there is a relationship. For this reason, in this article a case study is presented, which allowed to evaluate the relationship between positive cases of COVID-19 and the multidimensional poverty index (MPI) in the city of Manizales, Colombia. The results of an exploratory analysis, obtained with the use of remote sensing data, are presented, which allowed to confirm the relationship in mention, and it is hoped that this can serve the municipal administration in its decision making.

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1. Introduction

In late 2019, the sudden outbreak of Coronavirus disease (COVID-19), which originated in the city of Wuhan, China, required the implementation of containment and mitigation measures that stopped the most populous country and the second largest economy in the world (National Health Commission, 2020; Wang et al., 2020; Zhang et al., 2020). Despite the measures adopted, the virus reached a global level, becoming a pandemic, and by October 2020 there were about 42 million cases and 1.14 million deaths, by the same date in Colombia there were about 990 thousand cases and 29,636 deaths, information consulted in (Google, 2020).

Recently, it has been announced that the COVID-19 pandemic should be assumed to be a syndemic (Horton, 2020), this denomination, for many unknown, offers a much broader observation by indicating that: there are two categories of diseases that interact within specific populations: the severe acute respiratory syndrome coronavirus 2 infection (SARS-CoV-2) and a series of noncommunicable diseases (NCDs). The aggregation of these diseases in a context of social and economic disparity exacerbates the adverse effects of each disease separately. This leads to thinking about social determinants of health (determinants of COVID-19 transmission) driven by socioeconomic conditions, which could include lack of access to education, as well as community, household and work circumstances that diminish a person's potential to fully achieve physical and mental health and well-being (Richmond et al., 2020), determinants that may be more evident in societies with high social inequalities.

In Colombia, society is far from being equitable, being a country of inequalities, where there are marked inter- and intraregional imbalances (Acosta Medina, 2013), reflected in a Gini index of 50.4, according to the World Bank (The World Bank, 2020), which places it as one of the most socially disparate countries in the world. These inequalities can be seen with the MPI multidimensional poverty index, which can be interpreted as an indicator of the risk of COVID-19 infection for the population (Alkire et al., 2020), because it allows for the assessment of conditions of: health (access to the system, mortality, nutrition), education (access to education and level of schooling), and housing (electricity, health systems, drinking water) (Niu et al., 2020; Njuguna and McSharry, 2017). In this sense, a high MPI indicates unsatisfactory health, education and housing conditions in the population, and a higher risk of COVID-19 infection, due to the need to go out to work on a daily basis, the high level of labor informality and the...
consequent difficulty in respecting confinement standards, in addition to the scarce application of biosecurity measures suggested by the World Health Organization (WHO) to prevent infection, and the deficiencies in drinking water, education and electricity service infrastructure.

The MPI in Colombia is calculated from an approach based on the Alkire and Foster methodology (Alkire and Foster, 2011; DANE, 2020a). This approach establishes 5 dimensions (educational conditions of the household, conditions of children and youth, health, work, access to public utilities and housing conditions) and 15 indicators, as shown in Table 1. According to Alkire and Foster (2011), should include the selection of dimensions, dimensional limits (to determine when a person is deprived in a dimension), dimensional weights (to indicate the relative importance of the different deprivations) and a poverty line (to determine when a person has sufficient deprivations to be considered poor). Each dimension has a weight of 20% and the indicators have the same weight within their respective dimension. In this case, households are considered poor if they are deprived in at least 33.3% of the indicators.

This local panorama generates an interest in carrying out our study to evaluate the relationship between the COVID-19 pandemic and the MPI in the city of Manizales, and in this way to achieve an approach to the understanding of this pandemic as a syndemic, which is important to evaluate decisions that should be taken in the scenarios of economic and social reopening, and to generate an approach that considers the socioeconomic determinants, given that such determinants, such as poverty and overcrowding, as described by Manrique et al. (2009), between 1918 and 1919 during the influenza pandemic in Colombia, accentuated lethality. To achieve this, remote sensing data are used in this study, since it provides information that can help understand the spread of diseases and their relationship to social and environmental factors (Saran et al., 2020), which is framed by geography and medical mapping (Kuznetsov et al., 2020). In 2006 (Tran and Raffy, 2006), they demonstrate that large-scale information data,

Table 1
Description of dimensions, indicators and weightings used in the construction of the municipal multidimensional poverty measure from a census source in Colombia.

| Dimension and weighting | Indicator name and weighting |
|-------------------------|-----------------------------|
| Household educational conditions 0.2 | Low educational attainment 0.1 |
|                         | Illiteracy 0.1 |
| Conditions of children and youth 0.2 | School non-attendance 0.05 |
|                         | School backwardness 0.05 |
|                         | Barriers to access to early childhood care services 0.05 |
|                         | Child labor 0.05 |
| Work 0.2 | Economic dependency ratio 0.1 |
| Health 0.2 | No health insurance 0.1 |
| Housing conditions and access to public services 0.2 | No access to improved water source 0.04 |
|                         | Inadequate excreta disposal 0.04 |
|                         | Inadequate flooring 0.04 |
|                         | Inadequate exterior walls 0.04 |
|                         | Critical overcrowding 0.04 |

Fig. 1. Location map of Manizales.
such as remote sensing data, could be used to build a model of the spatial and temporal dynamics of a vector-borne disease.

On the other hand, remote sensing data have allowed some authors to propose strategies for the management of COVID-19 during the pandemic (Kanga et al., 2020c) defining risk zones and permitting activities in relation to the area's affectation. Kanga et al. (2020c) and others to analyze the pattern of human behavior and environmental data such as air and water quality. With respect to air quality, Berman and Ebisu (2020) have found that exposure to pollution could affect the risk of mortality from COVID-19, in turn (Liu et al., 2020; Nichol et al., 2020), indicate that the air quality index (AQI) in China decreased from January to March 2020, due to the reduction in industrial production and vehicle use, which shows that the spread of COVID-19 has a significant impact on daily lives and the environment. In relation to water quality during the pandemic, between March and April in India, turbidity indicators improved (Garg et al., 2020). In relation to the social dynamics and the risk associated with COVID-19 infection, authors such as (Kanga et al., 2020a; Ranga et al., 2020) have proposed risk indices such as proximity to hotspots, total population, population density, availability of clean water and associated land use/land cover, poverty index, urban, rural areas and water bodies. On the other hand, authors such as (Meraj et al., 2020), have conducted studies on the relationship between the increase in temperature and the spread of COVID-19, obtaining as a result that this increase does not affect the spread of COVID-19, but they clarify that it is necessary to replicate these studies in other regions and evaluate other additional factors such as evidence, social community structure and dynamics, government policies and demographic profile.

2. Materials

2.1. Study area

The study area is the city of Manizales, located in the department of Caldas, Colombia. The city, according to DANE (National Administrative Department of Statistics) projections and information from the municipality's planning secretariat (Alcaldía de Manizales, 2017), has approximately 400,000 inhabitants. The city is located in the central zone of the country, on the central mountain range which is a branch of the Andes (see Fig. 1).

2.2. Data sources

The purpose of this document is to evaluate how the MPI relates to the COVID-19 cases in Manizales. The literature review indicates that the risk of COVID-19 in many regions of the world is affected by social and economic factors, and therefore it is a syndemic. The city of Manizales is administratively divided into 11 communes (an
administrative unit in Colombia that includes several neighborhoods within a city). For each of the communes, it was necessary to establish MPI values, which were obtained from the National Administrative Department of Statistics (DANE) of Colombia (DANE, 2020b), but which are presented by blocks, which is a much smaller unit than a neighborhood, therefore it was necessary to obtain a consolidated MPI for the entire commune. The MPI was obtained as the average value of the MPI of all the blocks that make up the communes.

Another data used were the radiance values of the NPP_VDNES_L1 product of the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi-NPP satellite (NASA, 2020), in a window from January to April 2019, which represent the distribution and intensity of night-time illumination and may be associated with poverty levels (Elvidge et al., 2009; Shi et al., 2020). These remote sensing data were used to analyze the relationship that may exist between nighttime city lighting, MPI and the spread of COVID-19 in the city of Manizales. For this purpose, the monthly average nighttime radiances extracted from the “VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1” dataset were used (Earth Observation Group, 2020) containing Monthly average radiances composite images using nighttime data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB), available through the Google Earth Engine platform.

The illumination index was obtained by calculating zonal statistics by commune, using average radiances values for each commune for the period of analysis, from January to April 2019.

The information of the municipality as an administrative division was obtained from the geoportal (Alcaldía de Manizales, 2020) and the cases by COVID-19 of each commune were obtained from the reports issued by the Manizales City Hall in the social networks, from July 28 to October 31. It is clarified that it was not possible to conduct the study by analyzing the number of deaths by

![Behavior of number of positive cases by communes](image1)

**Fig. 3.** Behavior of number of positive cases of COVID-19 by communes.

![Transmission trend of COVID-19 by communes](image2)

**Fig. 4.** Transmission trend of COVID-19 by communes.
COVID-19 in each commune, since this information was not found in government repositories or on the social networks of the mayor’s office. With the previous data a table was generated (see Table 2) with the following fields: Commune, MPI, area, population, cases by COVID, density of positive cases COVID-19 and aging index.

3. Results and discussion

The city of Manizales has an MPI that varies between 4.9 and 16.09, having that the highest values are had in zones of the periphery of the city, this is possible to see it in the map of the Fig. 2. Based on the bibliography consulted, the hypothesis was formulated that in the municipalities with a higher MPI, there should be a higher concentration of positive cases for COVID-19. In order to evaluate the behavior of COVID-19 and its relationship with the MPI, some graphs were generated from the data obtained, which showed that each one of the municipalities has a different behavior in terms of COVID-19 transmission, which can be seen in the Fig. 3, that the transmission speed has also been different (see Fig. 4), and finally that the density of cases, given in cases/m² is different as seen in the map in Fig. 5.

The above results allowed us to approach a response on the relationship between the MPI and the behavior of the COVID-19 in the city’s communes. This behavior was finally shown by graphing the MPI and COVID-19 cases (see Fig. 6), where it is possible to see that as the MPI decreases, so do the COVID-19 cases. This is supported by a statistical analysis of the data, which indicates that
there is a strong positive relationship between the density of cases and the MPI, supported by a determination coefficient of 0.8024, that is, the power of explanation by the least squares model is 80.24% (see Fig. 7). With an ANOVA analysis (see Table 3) the value $F_0 = 28.4335029$ is lower than $F_a = 5.5914$, therefore, the results are located in the rejection region, which allows rejecting the null hypothesis and establishing that there is a linear relationship between the density of cases and the MPI. The level of confidence for the calculations was set at 95%, which gives a significance value of $\alpha = 0.05$. The analysis of variance in the regression yielded a $p - value = 0.0010847$ corroborating the hypothesis that the variables are linearly related.

On the other hand, and considering that lighting, obtained from remotely sensed data, as previously mentioned, can be associated with poverty levels and these in turn are estimated by the MPI, a comparison was made between cases of COVID-19 and lighting, observing a moderate relationship between these variables, which reflects that the greater the amount of lighting, the number of cases decreases (see Fig. 8).

The population density is different in each of the municipalities, therefore, and in accordance with authors such as Kanga et al. (2020b), Kanga et al. (2020a), a comparison was made between population density and COVID-19 cases, and it was found that there is no close relationship between both parameters in the city of Manizales (see Fig. 9). For example, the commune “La Fuente” has a high population density, but the number of cases is low compared to the commune “Ciudadela del Norte”, which has a significant number of cases, but a low population density. This may be

![Average MPI Vs Density of cases/m2](image)

**Fig. 7.** Correlation between average MPI and density of cases COVID-19 at Manizales.

| Source of variation | Sum of squares | Degrees of freedom | Mean Squares | $F_0$ | $F_a$ | $p - value$ |
|---------------------|----------------|--------------------|--------------|-------|-------|-------------|
| Regression          | 1805.50        | 1                  | 1805.50      | 28.43 | 5.59  | 0.0010847  |
| Error               | 444.49         | 7                  | 63.49        |       |       |             |
| Total               | 2249.99        | 8                  |              |       |       |             |

**Table 3**
Analysis of variance ANOVA of the regression.

![Average radiance vs COVID-19 cases](image)

**Fig. 8.** Radiance vs COVID-19 cases.
due to the fact that a commune such as “Ciudadela del Norte” has a large total area, but not all of it is built up, thus generating a low population density.

Finally, the data obtained in the present article allowed the generation of a spatial statistical map (See Fig. 10), which allows to visualize graphically the behavior of the COVID-19 infections, and its relation with the MPI and the illumination index.

4. Conclusions

The present study allowed exploring, in an initial way, the relationship between the behavior of the amount of cases by COVID-19, the MPI and the illumination in the city of Manizales. The results of the exploration indicate that in the communes of greater poverty (greater MPI) the density of cases per COVID-19 is greater, that is to say, that a relation exists between these two parameters and it is sustained by a coefficient of determination equal to 0.8024. This is possibly due to the fact that in these communes the social determinants of health (determinants of contagion by COVID-19) driven by socioeconomic conditions are higher. In these communes, most people do not have the economic resources to cover all the biosecurity measures established in the midst of the pandemic, they do not have private transportation and therefore are exposed to contagion by means of mass transport, many people work in the informal sector which does not represent a fixed monthly income and therefore cannot stop working since this would impact the household economy. On the other hand, it was possible to show a moderate relationship between lighting and cases by COVID-19.
On the other hand, we consider, based on the data obtained, that health strategies to contain the spread of COVID-19 should have a social approach, so that they are more holistic by considering other social dimensions that can negatively affect established health policies. Therefore, public health policies, in order to face this COVID-19 pandemic and future pandemics, should strengthen not only the health system and infrastructure, but also analyze other factors such as social, educational, access to public utilities, access to water sources, access to housing, i.e., the 15 indicators in Table 1 should be strengthened, which should have been foreseen by public policies knowing the disastrous indicators of the flu pandemic experienced between 1918 and 1919.

Finally, it is possible to advance further in the results obtained, having access to the primary data source on positive cases of COVID-19 and deaths by COVID-19 in the city of Manizales, gives a way to evaluate with big data techniques the relationship between positive cases and MPI, so that the local administration can plan policies to reopen and return to the new normalcy of the city in the midst of the pandemic. On the other hand, it would be interesting to conduct a similar study in many regions, so that the proposed relationship between the spread of COVID-19, MPI, lighting, and the inclusion of other risk indexes such as those proposed by some of the authors consulted, such as proximity to bodies of water, temperature, among others, could be validated in other environments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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