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Determination of the impact of natural disasters within the Colombian territory using Geographic Information Systems

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Abstract

This paper presents an analysis of the main natural disasters that occurred in the Colombian territory during 2019 and that generated some type of impact, especially with regard to the generation of human victims, deaths, injured, disappearances or material and economic losses. For this purpose, the events of greatest occurrence and affectation were taken, which correspond to Wildfires, Storms, Landslides and Floods. It was possible to obtain information of great interest related to the areas of the country most affected by the different types of events evaluated, being able to characterize these events geographically and on a time scale. For this purpose, use was made of Geographic Information tools, thus obtaining graphs that show the behavior of events by geographic areas of the country, as well as throughout the months of the year.

Keywords: Natural disasters, Geographic Information System, impact, victims

I. INTRODUCTION

Natural disasters are violent, sudden and destructive changes that occur in nature, the cause of which is not due to human activity, but to natural phenomena, that is, a natural disaster is part of a process or cycle of nature [1], frequently generating direct or indirect effects on people.

Natural disasters are increasing globally, both in frequency and complexity. The importance of knowing them lies in the possibility of being able to determine the degree to which they are affected, since they cause deaths and injured, displace the population, damage infrastructure, hinder growth and severely hit economic activity [2]. Worldwide, in 2019, natural disasters affected about 95 million people, causing approximately 11 755 deaths and leaving $ 130 billion in material losses. The number of events in 2019 is slightly above the average of the last 10 years. Floods and storms accounted for 68% of the events that caused the greatest number of people affected, and forest fires have attracted international attention, due to the increase in number [3]. That information reveals that studies and monitoring must be carried out in order to have a greater capacity to mitigate the damages and effects that these environmental catastrophes may produce.

In the case of Colombia, the issue of phenomena of natural origin and the disasters that they cause are of great interest because the country in recent decades has suffered many losses of human life and substantial material damage has occurred as a result of this situation. An example of this is the Armero catastrophe in 1985, which left more than 20,000 victims or the 1999 Armenian earthquake, which left large economic demands and a significant number of victims [4]. For this reason, Colombia is positioned as one of the countries with the highest risk of natural disasters in the world, being classified as one of the countries with the highest mortality due to these events [5]. Based on the above, it is essential to have a complete knowledge of the most common types of phenomena and the most common areas of involvement.

The classification of natural disasters is broad and their occurrence is closely related to the geographic location and the climatic conditions of the site. This type of event is known as an event, which is nothing more than the phenomenon, natural or not, which once triggered, produces adverse effects on human lives, health and/or the economic and social infrastructure of a community [6]. Examples of these events are earthquakes, hurricanes, floods, volcanic eruptions, tsunamis, among others; being the most common in Colombia and causing the greatest loss of life, floods and landslides [5].

Geography Information Systems provide useful tools for modeling and estimating that help prevent or mitigate the terrible effects that these natural disasters can cause. Within them, there are models that help to regionalize by geographical areas and make classification maps of events, as is the case of the Jenks Natural Breaks algorithm, which is a standard method to divide a set of data into a certain number of homogeneous classes [7].

The purpose of this work is to analyze the information regarding the most common unintended natural disasters (events) that occurred in Colombia during 2019, in order to obtain relevant information related to the areas of the country most affected by the different types of events evaluated, being able to characterize these events geographically and on a temporal scale and analyzing the effects that they caused throughout the Colombian territory. For this purpose, Geographical Information tools were used, thus obtaining figures that show the behavior of the events by geographic zones of the country, as well as throughout the months.

Additionally, summary tables of the effects produced and maps of events at the regional level are presented, in which zoning was established in function of the occurrence or frequency of the events.

II. MATERIALS AND METHODS

Data on unintentional natural events that occurred during 2019 were reported by the

Unidad Nacional para la Gestión del Riesgo de Desastres (UNGRD), and deposited in the public data repository of the Gobierno Nacional de Colombia [8]. The information consigned in the database corresponds to natural or anthropic events that occurred throughout the Colombian territory, and that caused damage to people, material goods or the environment, and that were reported to UNGRD, which it is the state entity that is in charge of directing the implementation of disaster risk management, attending to sustainable development policies, and coordinating the operation and continuous development of the national system for disaster prevention and care [9].

For the present work, the most frequent events that occurred in the entire study area were selected. The information contains reports from January 1, 2019 to December 31 of the same year. During this period, a total of 4,436 events with the aforementioned characteristics were reported, which were classified into 34 categories of unintentional natural disasters. The four categories that had the highest prevalence in the entire territory were chosen, yielding 3686 events, that is, 83% of the total reported events. The four selected categories were the following: Wildfires, Storms, Landslides and Floods.

In the processed data, information related to the description and location of the events, the impact caused by them, the support of the national disaster risk management fund in response to the emergencies generated, data about the decrees of public calamity and emergency monitoring and control. For the present study, only the first two items were studied, related to the description and location and the impact of claims.

In the case of description and location, the information is discriminated by temporal space, as well as by geographical space; being recorded day by day depending on the occurrence of events, as well as the location by municipality and department, which adds great value to the data when conducting analysis and looking for behaviors based on these. On the other hand, within the effects we can find the number of people killed, injured, missing, affected, affected families, destroyed and damaged homes, as well as the number of hectares of territory affected by the events.

The objective of this study is aimed at constructing some tables where the effects generated by unintended natural events are shown, both temporally and geographically. Similarly, Geographical Information Systems (GIS) tools are used to create event maps, which graphically show the events that occurred throughout the year by geographic regions, which in the case of Colombia, corresponds to the departments that make up the country.

In Fig. 1, a summary of the number of reported events is presented, broken down by departments, where the relative distribution can be seen in ascending order, which facilitates the determination of the ranking of the departments, with regard to the occurrence of events during the year 2019.

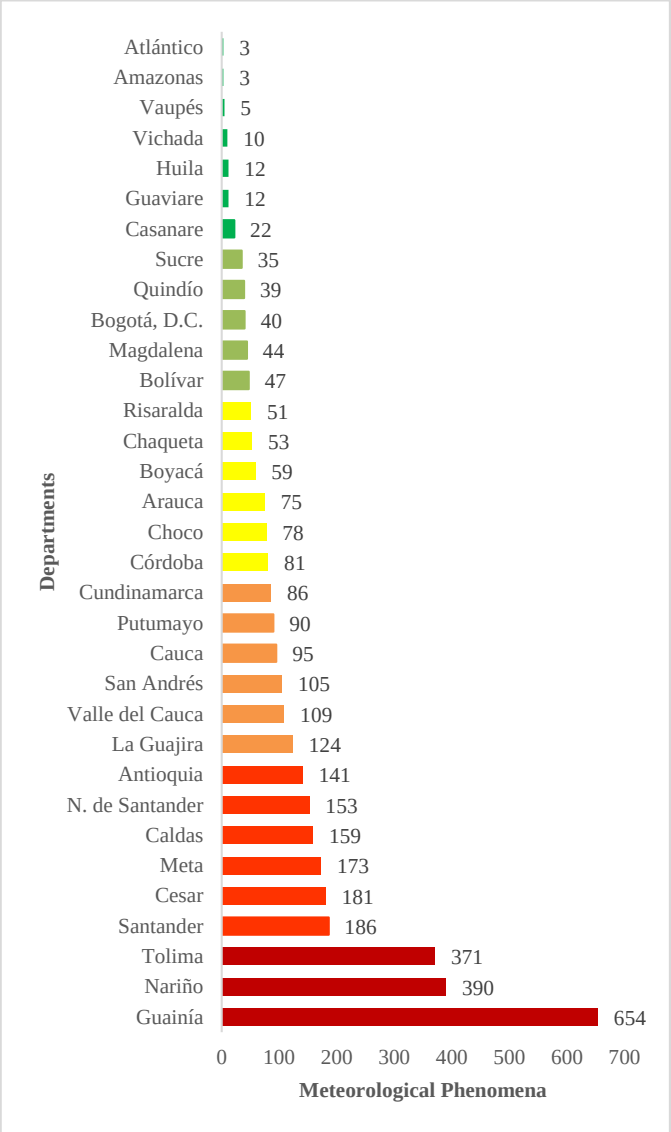

Fig. 1. Total events by departments

From the data collected, a filter was made with the relevant information for this work, which was organized using the Excel tool, filtering the selected natural events and the study variables of interest.

As a first measure, the information was organized into tables, which contain data on events by date, by location, and by impact, thereby achieving the ability to build summary tables and graphs that allow a better understanding of the events and their effects in Colombia.

Some Figures were built that represent the events, depending on the geographical location and from the months of the year, in order to visualize their behavior during the year. Additionally, some tables were built showing the effects produced by the events, again discriminated by department and by months of the year.

On the other hand, making use of Geographic Information Systems, maps of Colombia were generated in which the information for the four events is presented, in order to graphically show the number of events reported by department and to be able to categorize the regions with the highest number of emergencies during 2019. For this purpose, the Argis ArcMap software was used, with which it was possible to categorize the departments by number of registered incidents. This process was carried out based on the data classification method called “Natural Breaks Jenks”. In this optimization method, the classes are based on the natural groupings inherent in the data. Rankings are created so that similar values are better grouped and differences between classes are maximized. The entities are divided into classes, whose limits are established where there are considerable differences between the data values [10], [11]. This method was introduced in the middle, in 1977, as a method for the "optimal classification of data", and the procedure used is mainly based on Fischer's "exact optimization" method, developed in 1958 [12], [13]. This method was developed specifically for its application in the analysis of geographic data and has emerged as a standard geographic classification algorithm, so that it is within the classification algorithms of the software used [7].

Based on the previous procedure, the figures and tables obtained in the present study were elaborated.

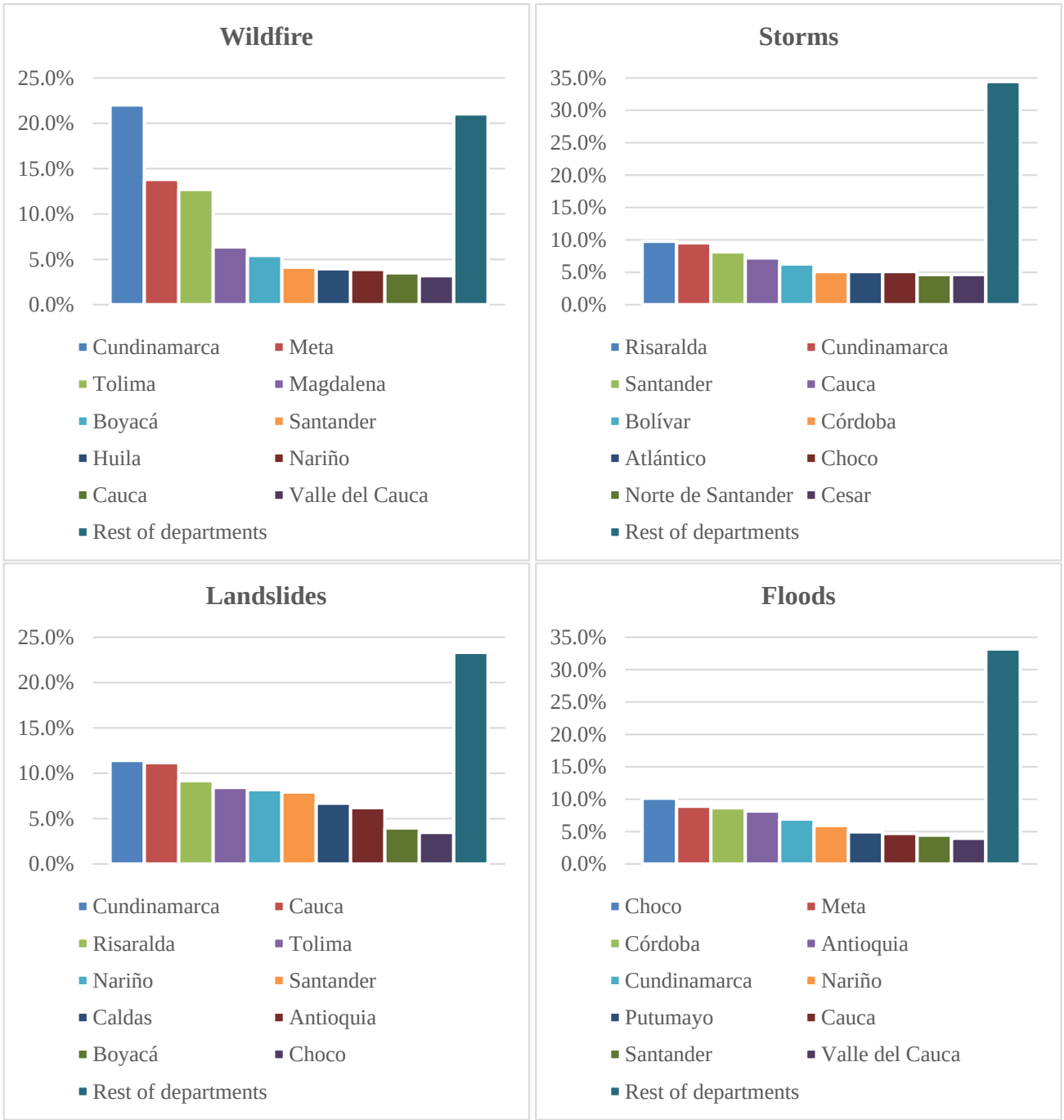

Fig. 2. Natural events by department

III. RESULTS

Tables and Figures were constructed that relate the four events with the highest occurrence in Colombia during the year 2019, where the relationship of the occurrence of events based on geographical location and time is looked at. Tables are also presented showing the effects of the incidents.

Additionally, the maps prepared for each event are shown and the frequency of the same for each department is shown.

Table 1. Effects of events by department

Departments	Deaths	Injured	Missing people	Affected people	Affected families	Destroyed houses	Damaged houses	Hectares affected
Amazonas	0	1	0	1	0	0	0	5
Antioquia	10	16	1	5662	1333	25	1101	1226.3
Arauca	0	0	0	5242	1888	71	853	10510.4
Atlántico	1	4	0	3996	1491	1	1118	85
Bogotá, D.C.	0	0	0	546	139	0	116	166.78
Bolívar	1	3	0	25601	7583	23	4425	1071.5
Boyacá	0	1	0	575	245	11	36	5407.1
Caldas	9	10	0	658	153	9	215	36.5
Chaqueta	2	5	1	4079	1080	5	1070	2.5
Casanare	3	0	0	306	59	0	32	22314
Cauca	33	6	0	15740	3270	68	1401	4987.6
Cesar	3	0	0	6015	1283	75	895	2225
Choco	2	4	0	78116	17171	38	5391	2462
Córdoba	0	0	2	23825	8443	6	3429	1458
Cundinamarca	2	7	0	5279	1967	36	1224	6156.2
Guainía	0	0	0	40	8	1	6	15
Guaviare	3	0	0	10375	2074	0	13	248
Huila	7	5	3	1026	208	0	194	5008.7
La Guajira	1	0	0	8283	1913	22	1910	8894
Magdalena	2	14	0	6268	1853	14	1725	5578.5
Meta	0	1	0	5449	1724	24	337	29984.7
Nariño	5	6	0	21329	5607	114	719	3465.05
Norte de Santander	1	5	0	286	56	2	54	2021
Putumayo	0	0	0	12265	5766	104	2945	1851.5
Quindío	1	1	0	1152	232	3	228	46.8
Risaralda	8	15	0	5233	1650	16	1141	48.1
San Andrés	0	0	0	18	4	0	4	0
Santander	2	3	0	4176	915	2	913	836.2
Sucre	0	0	0	8120	1771	0	1771	171.5
Tolima	6	34	0	1643	384	12	354	36132
Valle del Cauca	2	1	0	7069	2546	13	936	584.3
Vaupés	0	0	0	116	22	0	20	0
Vichada	0	0	0	455	121	0	92	604

In Fig. 2, the occurrence of the events discriminated by type of event and geographical area (department) is shown, showing the ten geographical areas where the greatest number of events were reported and grouping the rest in a category called "Rest of departments".

In a complementary way, a figure was built in which the behavior of the four selected natural events is presented throughout the months, being able to appreciate how each event fluctuates month by month and the relationship it has with the climatic conditions of that time or month of the year. These results are shown in Fig. 3, in which it can be seen that each type of event has a time of year where they predominate and is linked to the climatic conditions of the area.

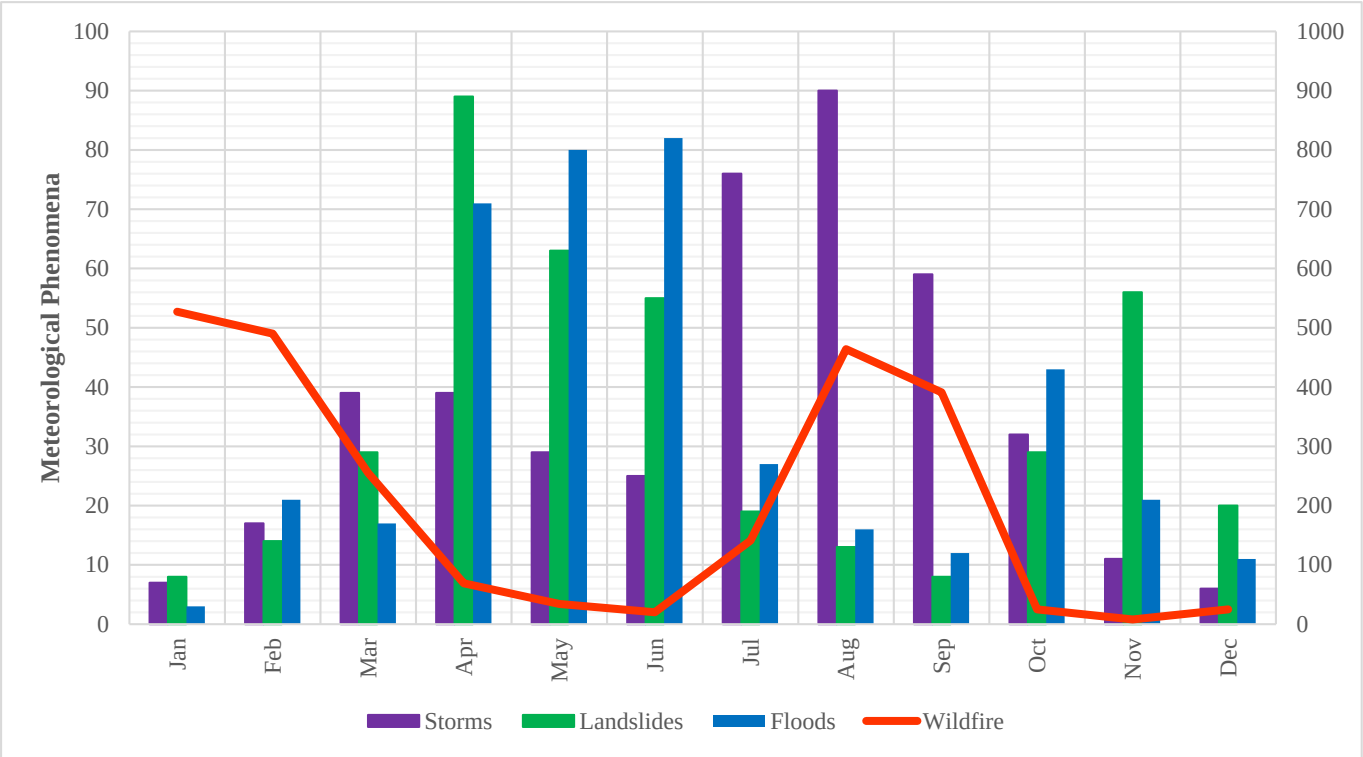

Fig. 3. Events reported by months of the year

Tables 1 and 2 show the effects that occurred in different departments and in different months of the year, respectively. The tables show the number of dead people, injured people, missing people, damaged people, destroyed homes, damaged homes and the amount of area affected by the events.

Table 2. Effects of the events by months

Months	Deaths	Injured	Missing people	Damnified people	Damnified families	Destroyed houses	Damaged houses	Hectares affected
January	2	1	0	1647	506	38	242	15718.95
February	2	1	0	19928	4345	105	1307	51572.4
March	7	18	0	19089	4364	62	1614	21489.13
April	46	27	0	26196	6698	108	2191	7425
May	7	7	1	48412	14818	128	8243	2672
June	14	14	4	59434	19183	98	7608	2535.5
July	3	5	0	23677	4828	71	3134	1555.9
August	1	14	2	12964	3263	8	3198	25184.1
September	5	5	0	15346	4564	38	3464	24312
October	9	20	0	18590	5161	12	2683	862.5
November	5	24	0	4695	1154	7	558	66.75
December	3	6	0	18966	4075	20	426	209

Fig. 4 shows the frequency and the effects by type of event. For this purpose, the five most representative impacts were selected, which were dead people, missing people, affected person, destroyed houses and area affected by natural events.

Figures 5, 6, 7 and 8 present the maps for the four selected event types: Wildfires, Storms, Landslides and Floods, respectively. The distribution by departments of the frequency with which unprovoked natural events were presented and reported throughout the country is graphically shown, being able to observe the departments hardest hit by each type of event and the regions most susceptible to such events during the year 2019.

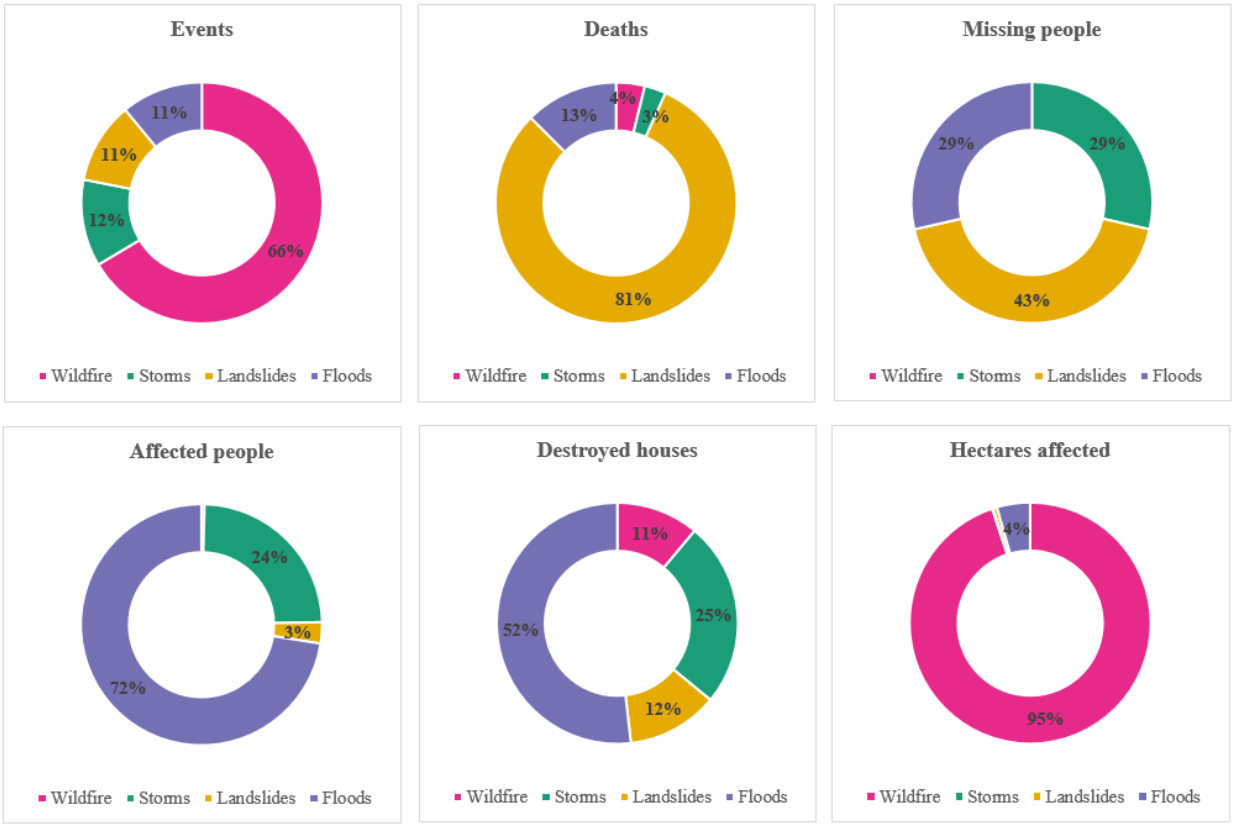

Fig. 4. Impact and effects by events

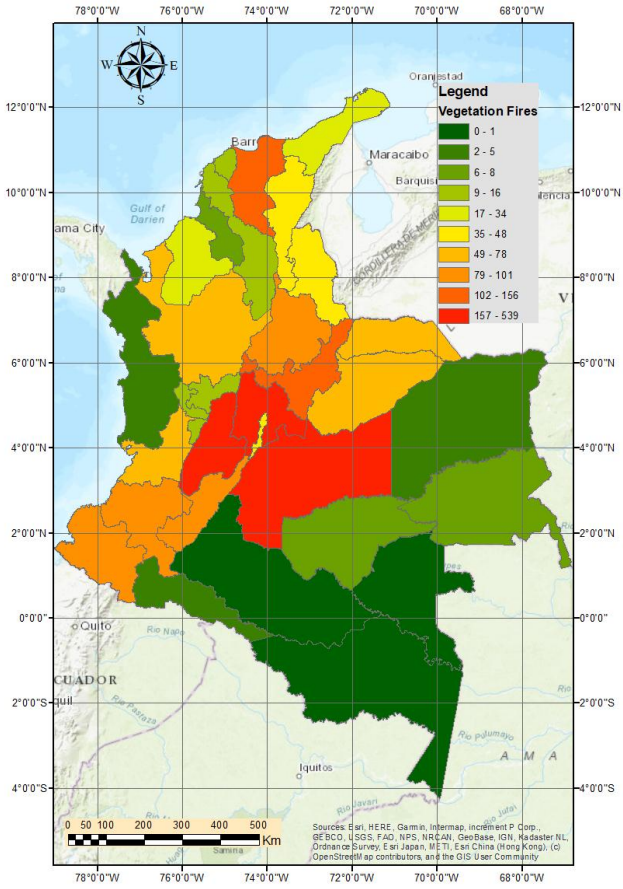

Fig. 5. Event map for Wildfires

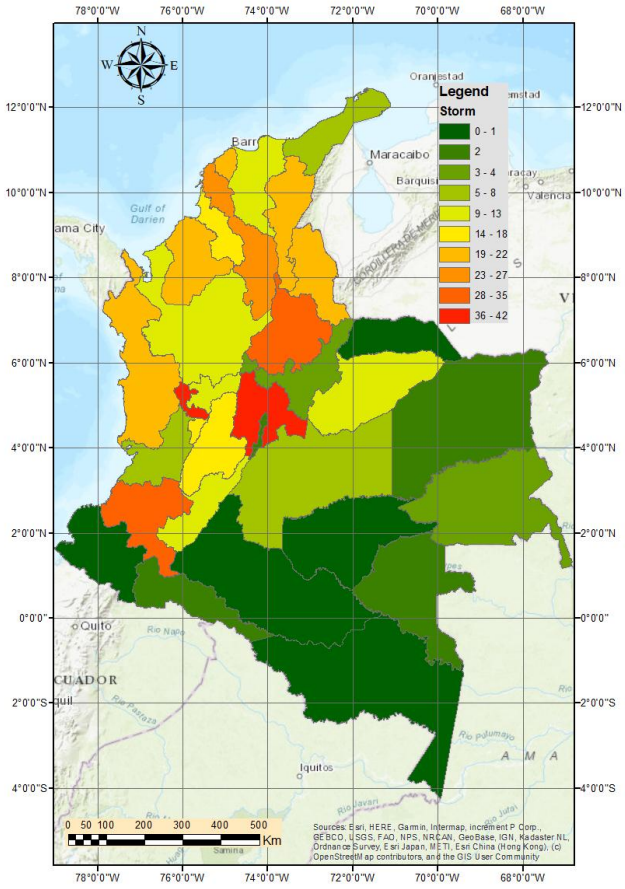

Fig. 6. Event map for Storms

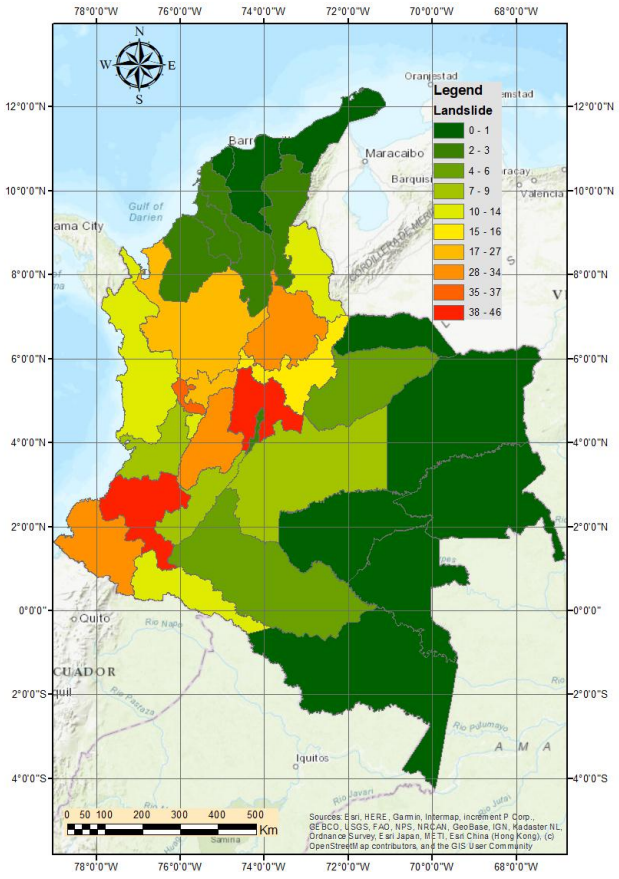

Fig. 7. Event map for Landslides

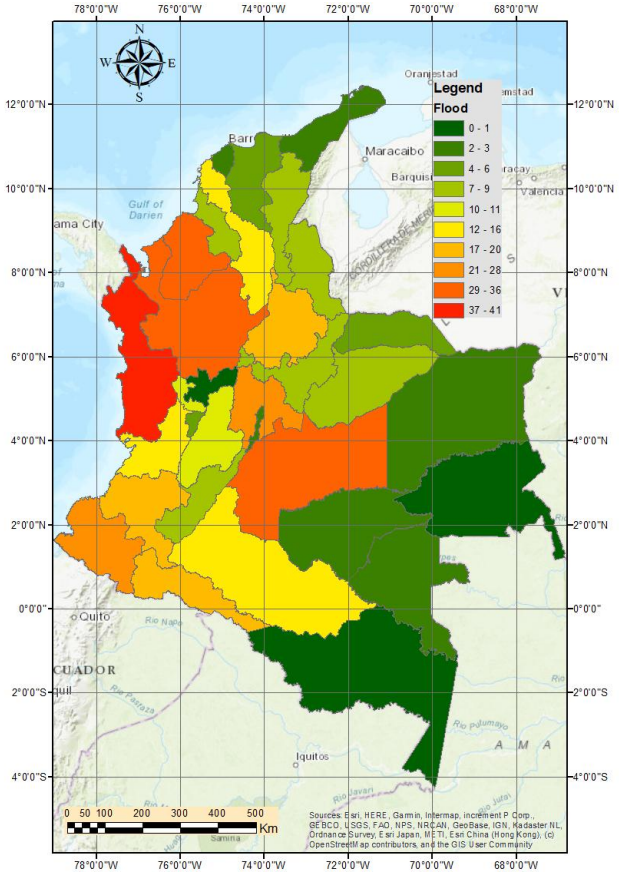

Fig. 8. Event map for Floods

IV. CONCLUSIONS

According to the information organized, filtered and processed and with the results obtained, it can be concluded:

Unprovoked natural events are closely related to the climate and geographical location of the area where they occur. It can be observed in Fig. 3, that forest fires occur more frequently in the months in which the country goes through its summer season and they tend to decrease in the months where there are rainy seasons. On the other hand, the events of storms, landslides and floods intensify very notably in the months in which the rainy season hits the country, being able to observe the relationship that these three events have with the common these seasons of the country.

From Fig. 4, it can be concluded that the event with the most frequency in 2019 corresponded to fires, while the remaining events have similar frequencies, in addition, the largest amount of land affected was caused by forest fires. It is observed that the event that caused the most deaths were landslides and those that left the most people affected and houses destroyed were floods, followed by storms.

In relation to the geographical distribution of the events, it can be established that the vast majority of the fires reported and that left damages occurred in the central area of the country, predominantly in the departments of Cundinamarca, Meta and Tolima, in addition a trend towards the north of the country, where the department of Magdalena was the worst hit. Regarding the storms, the departments where the most events occurred were Risaralda and Cundinamarca. In this case, the trend is towards the Pacific and Caribbean coast of the country, in whose departments it is observed that the frequencies of the storms reported were higher compared to other departments of the country. In the case of landslides, the departments with the greatest effects were Cundinamarca, Cauca and Risaralda. It can be seen that the trend is that most of the landslides that were affected are found within the mountainous area of the country, that is, in the departments where the Cordillera de Los Andes system develops. Finally, from the flood map, it can be concluded that the departments where this type of event occurred most frequently were Chocó, Meta, Córdoba and Antioquia. On the other hand, it was observed that the peaceful area of the country is the most affected during the year by this type of event, which may be due to the fact that it is the area with the highest rainfall within the national territory.

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