Hazards Analysis in the Canton La Unión, Cartago, Costa Rica

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ABSTRACT

The hazards from the canton La Unión were identified, analyzed, and described. A value ranging from 0 to 1 was assigned to each threat in the Minimum Geostatistical Units (MGU), to estimate the dangers density in the study area. This article shows the spatial distribution of such index. The manifestation of several natural and anthropic events forces to investigate and understand such processes, in order to improve Disaster Risk Management (DRM) in the Canton and provide inputs to the Local Government to carry out such work. The investigation required a bibliographic review to know the impact of past incidents, field surveys to determine the spatial extent of the threats, and the calculation of a hazard's density index. According to the results, earthquakes are the main danger in La Union and the Center, South and West of the canton are the areas with the highest hazards density.

Keywords: Hazards, Index, density, landslides, floods.

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I. INTRODUCTION

The distribution of hazards in the canton (Fig. 1) was analyzed with the Geographic Information Systems (GIS) tool, in order to estimate the Hazard Density Index and carry out their respective cartography.

Different natural and anthropic hazards such as earthquakes, fall of volcanic products, floods, landslides, and gas leaks strike the studied area. The frequency of floods has been increasing in recent years, the landslides affect the zone, and technological incidents, like toxic gas leaks, have caused emergencies in the canton. These facts must be investigated

and studied to protect the population from the impact of such hazards.

This work aims to improve the Disaster Risk Management (DRM) in the Canton and gives the Local Government a basic input for that. Article 14, subsection h, of the National Law on Emergencies and Risk Prevention, No. 8488, indicates that the responsibility to face the problem of vulnerability lies, primordially, in the Local Government. For this purpose, local authorities require information on risk conditions, effective land use policies, regulatory plans, control measures and local organization.

Fig. 1. Studied area.

The study required bibliographic reviews and field surveys to obtain information about the hazards. The collected information was used to calculate the Hazard Density Index [1]-[5] of the studied territory. Each danger was quantified in each one of the 775 Minimum Geostatistical Units (MGU) of La Unión (A MGU is a territorial unit used by the National Institute of Statistics and Census to carry out the national census).

The results indicate that earthquakes, floods, and landslides are the more important hazards of La Unión. Gas leaks that have caused emergencies have also struck the studied area. The hazard density index map shows higher concentrations in the Center, South and West of the canton.

II. METHODOLOGY

The identification of hazards required bibliographic review of both specialized documentation and journalistic reports of incidents relevant to the study. The collected information came from public institutions such as the National Meteorological Institute, the National Commission for Risk Prevention and Emergency Attention (CNE, acronym in Spanish), the National Territorial Information System (SNIT, acronym in Spanish), the Costa Rican Petroleum Refinery (RECOPE, acronym in Spanish) and the National Institute of Statistics and Census (INEC, acronym in Spanish). Field work and interviews were carried out to find out the existence and extent of the hazards.

The possibility of an explosion due to fuel leak at gas stations was estimated using the storage capacity data and analysis made at gas stations in Mexico [6]. A linear and proportional relationship between the data of the gas stations investigated and the data of the Mexican gas stations (already calculated) was used to find out the maximum distance reached by an explosion. The radii of influence of toxic gases were taken from Sánchez et al. [7], who calculated the dispersion of substances during incidents in the main industries of the Greater Metropolitan Area of San José city, the capital of Costa Rica. Data supplied by RECOPE were used to trace the trajectory of the pipeline.

The hazards were individually mapped using ArcGis 10.4 Software. Such mapping was based on their spatial extent according to existing information and data collected in the field. A weight was assigned to each threat according to their frequency and damage [8]. The general hazard map was created with measurements corresponding to each of the 755 Minimum Geostatistical Units (UGMs) of the canton. To do this, a value between 0 and 1 was assigned to each hazard in each UGM. The resulting values were used to create a Hazard Density Index [1], [2], [4], [5].

Hazard scores calculated in the UGMs were used to create variables. These were standardized by dividing the threat score for each UGM by the maximum UGM value for a given hazard. The results were added and divided by the total number of variables present in a UGM and as a result, a density index of value between 0 and 1 was obtained, with the highest value indicating the greatest hazard.

III. RESULTS

Earthquakes, volcanic ash fall, landslides, floods, toxic gas leaks, potential explosions at gas stations and fuel leaks in the Polyduct of the Costa Rican Petroleum Refinery (RECOPE) are the hazards existing in the studied area. The earthquakes greatly affected La Unión in the first decades of the 19th century when they generated material losses (infrastructure). The 1910 Cartago Earthquake had an intensity of VI and VII in the Tres Ríos, where there was also damage in the infrastructure [9]. The 1912 Tres Ríos earthquake also caused much damage in that community [10]. This event destroyed the school and City Hall, opened several cracks in the streets around the soccer field and dried up the Chiquito river [10].

Floods are the most frequent hazard in the canton. There were important events in 1994, 1999, 2003, 2006 and 2015 [7], [11]-[16]. Floods usually occur in Río Azul where the local authorities zoned some sectors to grant construction licenses [17]. There is evidence of flooding in the center of Tres Ríos and in the San Diego and San Juan districts since the first half of the 20th century [18]. The water flows descending from the hills during the rainy season are a danger for the communities located at the bottom [11]. To date, the floods have caused damage to homes and a few deaths.

The volcanic hazard includes ashfall, lahars and gas emissions. According to existing data [19], volcanic ashes from the Irazú and Turrialba volcanoes directly affect practically the entire territory and the population of the canton. Gas emissions would affect the general population, as well as crops and livestock [18].

Landslides occur in the areas of abrupt relief, which are located mainly southward of the studied zone. The Río Chiquito landslide [20], [21] is the most important one in the area. Communities affected by landslides in the past are (Fig. 2): Calle Carvajal [22], Calle Vieja [12], Rincón Mesén [13], Santiago del Monte [23], Residencial Génova [24], San Vicente [25], [26], El Fierro [10], Calle Díaz [27] Barrio Holandés [15], Miriam Beker [14] and Barrio Tirrá [28]. Major events have caused destruction of homes, damage to roads, cracks and loss of human life.

Technological hazards include industrial gas leaks, gas station explosions and fuel leaks in the RECOPE pipeline. The most recent and shocking technological incident occurred in 2002, when there was a Chlorine gas leak at the Irex company, located in the Concepción district. This incident affected the population of several districts [16], [29]. There are three gas stations in the canton (Ayarco, Tinoco and Total) whose corresponding maximum impact radii due to an explosion are 32, 37 and 34 meters [30]. Fortunately, there has never been an incident in any of these stations. In some sectors of the RECOPE pipeline there are human settlements that have invaded the established 15-meter protection zone but, there has never been an incident due to fuel leaks in such pipeline.

A. The Hazard Density Index

The study and analysis of hazards culminated in the Hazard Density map shown in Fig. 3. According to the results, the areas with the highest hazard density are in the districts of San Diego and Río Azul. The highest hazard density is due to the presence of at least 4 threats. Earthquakes, floods, and volcanic ash fall are in all those areas of maximum hazard density. Most emergencies of these zones are generated by floods and the incidents are favored by physical conditions such as the proximity of houses to the rivers. In the south of the study area (Río Azul) there have already been deaths caused by landslides.

The medium hazard density covers the southern and central-west of the canton. The index value of these areas is

lower because their maximum threats is 3 (earthquakes, ashfall and some other). In the south of the district there is potential for landslides, but no flooding and towards the central west there is potential for gas leaks, but not for floods or landslides. That is why the number of threats in these areas does not reach the value of the higher density areas; therefore, their resulting score is medium. Concepción district has several areas of medium density index which is due to the presence of technological hazards like industrial gas leaks.

The low hazard density predominates in most of the canton, which is due, according to the analysis, to the presence of few threats. In such areas the two most common dangers are earthquakes and volcanic ash fall, which affect the entire territory equally. In these zones there may be even one more threat but, by weighting, the index score is equal to

or less than 0.25. In these areas there are practically no landslides or floods. In addition, the frequency of occurrence of the hazards is low. As an example, the 1912 Tres Ríos earthquake seriously affected the canton but, however, events like this have not been repeated yet.

IV. DISCUSSION

The Canton La Unión is close to two active volcanoes and has geological faults, irregular topography and an important rivers network. In La Unión there are also gas stations, industries that use toxic gases and a pipeline to transport fuel. All these factors contribute to the occurrence of natural and man-made incidents. Both the impact of hazards and their density index are influenced by anthropic activity. Natural events would not affect the population so much if human beings had not gotten so close to dangers and had not been exposed to their strength and power. According to the results of this work, the hazards have not invaded the territory of the people, on the contrary, the people have invaded the limits of nature.

River basins and micro-basins have been altered in La Unión. This situation has not been adequately managed and the proper sustainable development of the canton has not been promoted. Environmental deterioration, as a product of urban developments, is more evident every day. The forest cover has been replaced by agricultural and housing uses. Deforestation eliminates the vegetation cover, leaving the soil without adequate protection, which favors surface runoff, soil erosion, river flow and their overflowing.

This work is a deterministic analysis and could be complemented with probabilistic studies. In spatial analysis, the information used sometimes does not have the detail required to make a more accurate analysis. Although the UGM is the smallest unit of analysis that can be used in the country, its size is not uniform and some of them are very large, which forces to distribute the value of an index throughout the area of the unit. This fact can generate uncertainty in the spatial analysis.

This work reveals that the magnitude of the damage caused by floods and landslides has increased due to human activity such as deforestation, the construction of infrastructure in protected areas, the presence of human settlement in high-risk areas, the advance of urbanization, the increase in the soil waterproofing and the mishandling of solid waste. Without these human contributions the impact of threats would be less.

Finally, the hazard density index obtained could serve to better understand the dynamics of the hazards in La Unión. The results will be an important input for risk management in the canton. Therefore, the future assessment of the vulnerability index would be useful to better determine the disaster risk of La Unión.

V. CONCLUSIONS

The more important hazard in La Unión is the earthquake. This threat has caused significant economic damage and losses but, fortunately, they only occur occasional or remotely. The second danger in order of importance is

flooding, which is very frequent and causes damage year after year. Landslides are significant and have caused fatalities, but they don't happen frequently. The toxic gas leaks have generated emergencies but no deaths and to date there have been no explosions at gas stations or fuel leaks in the pipeline.

According to the hazard density map obtained, the highest hazard density in La Unión is in the central, southern and western sectors and is due to the concentration of 4 hazards: earthquakes, volcanic ash fall, floods and landslides. The districts with the highest hazard density are Concepción, San Diego and Ríos Azul. In the last two districts are the areas with the highest hazard density. In general, most of the canton has a low hazard density.

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