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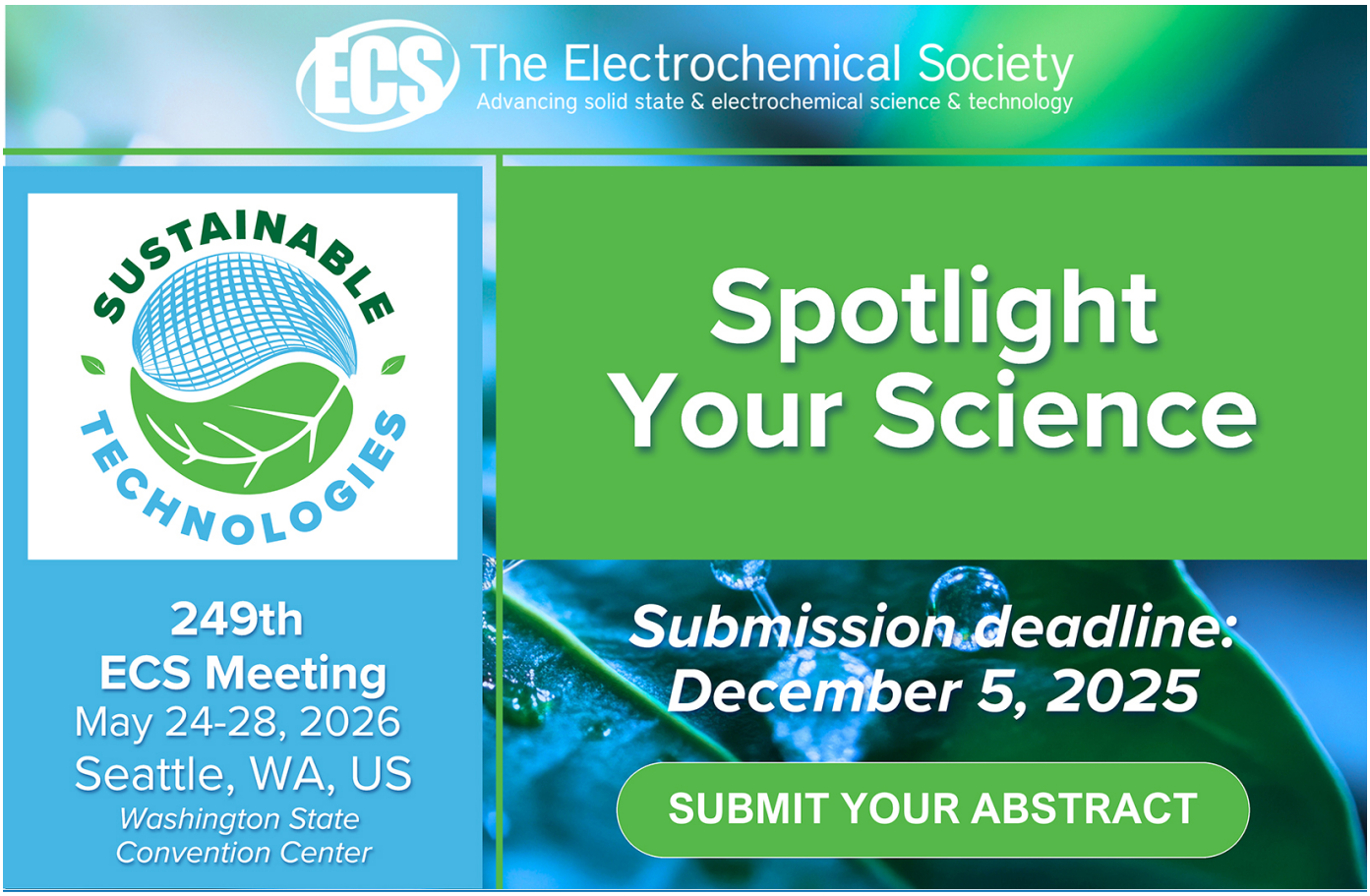
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Analysis of urban vulnerability before natural and anthropogenic hazards: Case study, human settlement Colinas de la provincia, municipality of Ocaña, Colombia

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Abstract: Urban vulnerability in human settlements located in areas susceptible to landslides is not subject to a danger assessment, since there is no basis to determine the probability of its occurrence in a certain period of time. Most evaluation procedures for the landslide hazard zoning employ a few urban components and subcomponents important or significant to estimate the relative danger. The danger evolution in such areas leads to make the population vulnerable to threats, whether natural or anthropogenic, that jeopardizes its integrity. In this research, an urban vulnerability analysis was carried out using a methodology that established the susceptibility of an urban settlement to be affected by natural and anthropic factors. The latter becomes an input so that the authorities in charge of risk management can establish actions to reduce this vulnerability in a certain way, through plans that contain actions, whether preventive or corrective; in order that these actions eliminate real and potential causes of the presented problem, thus reducing the situation of vulnerability and therefore the risk.

1. Introduction

In general terms, vulnerability can be defined as the physical, economic, social, environmental or institutional susceptibility or fragility of a community to be affected or to suffer adverse effects in case of a dangerous physical event occurs [1-2]; however, it is also understood as vulnerability [3]:

- The degree of loss of an element, or group of elements, due to the probable occurrence of a disastrous event [4].
- The set of characteristics that affect the ability of a person or a social group to anticipate, face, resist and recover from the impact of a natural phenomenon [5].
- The physical, economic, political or social conditions that a community has and that make it susceptible to be affected or suffer damage in the face of threats, when located in spaces that are not suitable for urbanization [6].
- The exposure to risks and uncertainties that a community, town or city has, and the ability to resist, defend and overcome them; without excluding the social sectors [7].
- The conditions determined by physical, social, economic and environmental factors or processes that increase the community susceptibility and exposure to the impact of threats [8].
- The process where a discomfort is unleashed related to the social conditions of disadvantage of a population, social exclusion sectors and lack of opportunities to face projects of security and confidence in their environment [9].

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- The ability that a community has to face and overcome the effects of threats, whether natural or anthropic [10].

Vulnerability is related to the predisposition to suffer loss or damage of human beings and their means of subsistence, as well as their physical, social, economic and support systems, before the occurrence of natural and anthropogenic phenomena; so, its evaluation requires knowing different physical and social aspects related to the threats and their impacts on the elements exposed in the study areas [11]. Some authors relate vulnerability to the urban degradation derived from insufficient investment, poor constructive quality and poor planning [12-13].

Although indices have been obtained to evaluate different types of vulnerability to specific natural hazards such as landslides [14-15] in which different geotechnical data are considered that allow the evaluation of conditioning factors and triggers that influence the stability [16], methodologies have also been developed to analyze and assess the vulnerability of human settlements to natural and anthropogenic threats, considering their physical, technical, economic, social, political and environmental components, among others [17]. Some methodologies develop indicators to analyze and evaluate concepts associated with the vulnerability of different urban components, among which are territorial, organizational-structuring, functional-urban and building subsystems [3]; and others, identify and characterize the exposed elements to then evaluate the types of damages or effects expected in the different vulnerability scenarios [11].

The present research contemplated the analysis of urban vulnerability in the human settlement Colinas de La Provincia, Municipality of Ocaña, where there are physical, economic, political and social conditions that make it susceptible to being affected or damaged by natural or anthropogenic threats. Colinas de La Provincia was born in 2007 as an illegal settlement, due to the need for housing of many families with limited economic resources, mostly displaced peasants as a result of the violence unleashed by the armed conflict in the country.

When there is demand for housing and it is not easy to acquire them in the existing urban environment, people buy in inappropriate places to build because of low costs, increasing urban expansion and unplanned occupation [18], of sectors with high geomorphological susceptibility [19]. The settlement that informally emerged, was located on a hillside where instability conditioning factors and triggers such as: land use, geological and geotechnical, hydrological, and topographic conditions, geomorphology, human activity, among others, make it susceptible to the occurrence of mass removal phenomena and erosion problems [20-21].

2. Methodology

A vulnerability study is an important factor in the risk analysis and, the knowledge of its variables and indicators allow to understand its possible scenarios. Among the vulnerability factors are the weakness or susceptibility of human settlements related to the socio-economic, physical-structural, legal, political and institutional systems [22].

The urban vulnerability analysis carried out on the human settlement Colinas de la Provincia was developed based on the study performed by [10], which apply the methodology proposed by [17], that consists of five stages: initially, it must be made a threat assessment at the city level, the definition of urban areas, inspection of the study area, then a threat evaluation is made and finally, the vulnerability analysis is carried out. For this particular case, the methodological scheme detailed in Figure 1.

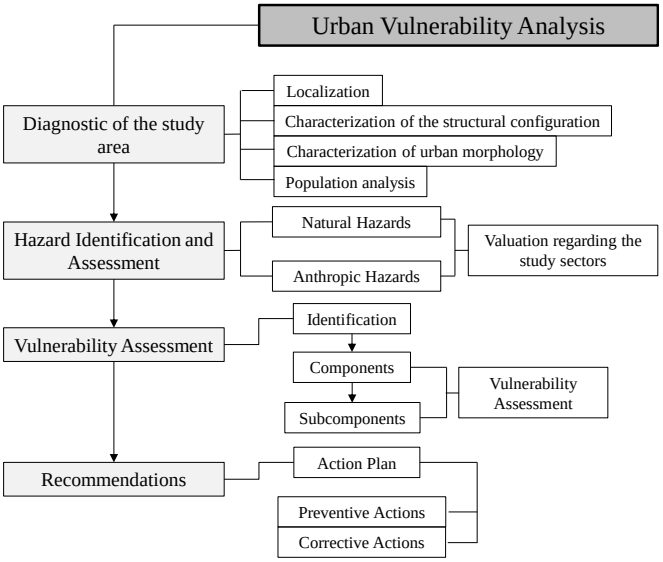


Figure 1. Project methodological scheme was presented, starting with a diagnosis of the study area, and later a threat identification and the vulnerability analysis, which allowed to propose an action plan as part of the recommendations to reduce the vulnerability levels.

3. Results

A vulnerability study is based on the analysis of the "Vulnerability factors" that derive in profiles, or tables that show through the characterization of those factors why and how the exposed elements are vulnerable [23]. The analysis of urban vulnerability that was carried out on the human settlement Colinas de la Provincia mainly considered the threats of natural and anthropic origin to which this settlement is exposed, to finally propose preventive and corrective measures that reduce the current condition of vulnerability.

3.1. Diagnosis of the study area through basic data collection

In this first phase of the research, a detailed exploration of the human settlement Colinas de La Provincia was made, which allowed to identify, organize and describe the current situation of the study area. The settlement location is shown in Figure 2.

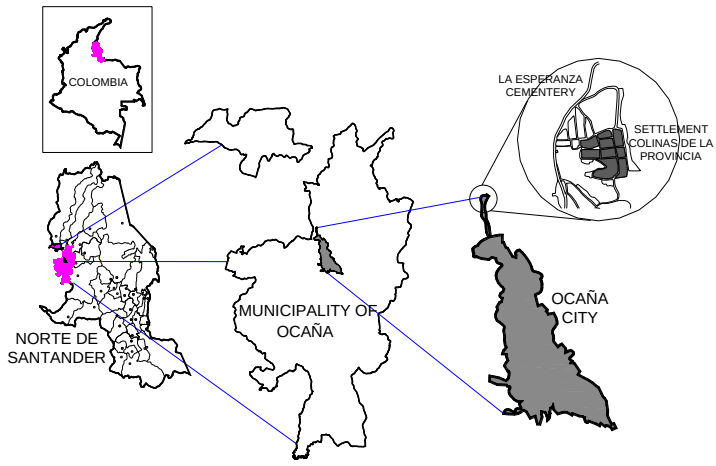


Figure 2. Location of the settlement Colinas de La Provincia, Municipality of Ocaña, Norte de Santander, Colombia.

Once the initial diagnosis of the study area is made, a formal exploration is made to consolidate the information which is collected through the implementation of files and interviews made to the population. To this phase the identification and evaluation of present threats is added, for which the study area was divided into 5 sectors identified as S1 to S5.

In the study it was possible to identify, that according to the structural configuration of the houses, 65.69% are made of brick or block without structural confinement, and do not have minimum

structural conditions according to the Colombian Standards for Seismic Resistant Design and Construcion (NSR 10) and only 9.65% meet these conditions. According to the morphological urban characterization of the five study sectors, an irregular and disorganized plan is identified with the evaluation in the different sectors, mostly collective housing and the use of land in the study area is residential, occupying almost 90% of the settlement.

The population analysis carried out in the study area shows that there are a total of 737 homes in the settlement, in which 32.93% of the population are men, 37% are women and 30.07% are children. Additionally, a population density analysis was made, observing that sector four (S4) has the highest density with a value of 0.0425 people/m^2.

3.2. Identification and assessment of present threats

In this stage, an identification was made of the different threats, natural or anthropogenic, present in the study sectors and whose evaluation is detailed in Table 1 where an assessment of them is shown, with a 1-5 assessment scale, being 5 for very high threat, 4 high threat, 3 medium threat, 2 low threat and 1 very low threat; the sum of these values can vary between 9 and 45 according to the identified threats; these threats are related to the danger, understanding the latter as the possible occurrence of a phenomenon, which can manifest itself in a predetermined place and time [24].

Table 1. Threat assessment according to study sectors.

Threat assessment by urban sectors according to Figure 2						
Threat	Type	S1	S2	S3	S4	S5
Natural Threat	Geological faults	4	4	5	4	4
	Landslides	5	5	5	5	5
	Soil and other material detachment	3	4	5	3	4
	Earthquakes	5	5	5	4	5
Anthropogenic Threat	Outbreaks of epidemic disease	3	5	3	3	4
	Overpopulation	3	4	4	4	3
	Insecurity	4	5	4	4	3
	Marginality	4	5	4	4	4
	Poverty	4	5	5	5	4
SUM		35	42	40	36	36

Based on the results of the previous table, the following is concluded: Values = 9 the threat is very low, values 9<X<=18 the threat is low, values 18<X<=27 the threat is medium, values 27<X<=36 the threat is high and values X>36 the threat is very high. That said, sectors S2 and S3 present a very high or severe threat, and sectors S1, S4 and S5 have a high threat.

3.3. Analysis of urban vulnerability in the different sectors of the study area

For the evaluation of urban vulnerability, a study of the urban components and subcomponents present in the settlement, detailed in Table 2, was made. Once the vulnerability level was determined by components and subcomponents, evaluation criteria were assigned with values from 1 to 5, which express the different vulnerability levels, with the value of 1 being the minimum valuation and 5 the maximum valuation. The sum of these values can vary between 37 and 185 and allows to obtain the qualitative value of the vulnerability for each study sector, which is quantified taking into account the following criteria: values = 37 very low vulnerability, values 37<X<=74 low vulnerability, values 74<X<=111 medium vulnerability, values 111<X<=148 high vulnerability and values X>148 very high vulnerability. In total, 28 urban subcomponents were identified; the vulnerability assessment is detailed in Table 2.

From the vulnerability assessment, it is possible to affirm that the five study sectors have a high vulnerability, and mainly correspond to the physical, technical and institutional components, the technical component being the one that involves the existence of adequate construction processes,

among the which can be considered those related to hillside stabilization [21]. Additionally, weaknesses mainly appear in the road network, the urban morphology, the lack of machinery and infrastructure, the citizen security and the lack of municipal support.

Table 2. Urban vulnerability assessment according to study sectors.

Vulnerability valuation by urban sectors according to Figure 2						
Component	Subcomponent	S1	S2	S3	S4	S5
Physical component	Quality of housing construction	4	5	5	5	4
	Technical Networks	4	5	5	5	4
	Road network	5	5	5	5	5
	Urban morphology	5	5	5	5	5
	Urban density	3	5	4	4	3
	Population density	3	5	5	4	3
Technical Component	Existence of equipment and machinery in the sector for emergency prevention and response	5	5	5	5	5
	Physical structures and constructions built with adequate techniques	5	5	5	5	5
Economic component	Level of family income facing a threat or calamity	5	4	4	5	5
	Unemployment in the sector	3	3	4	3	4
Social Component	Community organization	3	3	3	2	2
	Citizen participation	3	3	3	3	3
	Geographic location to the health centers and type of health provider	3	3	3	3	3
	Access to media	4	4	4	4	4
Cultural component	Citizen security	5	5	5	5	5
	Community knowledge of present vulnerability	5	5	5	5	5
	Local radio or television programs on disaster prevention	5	5	5	5	5
Political component	Community participation in local decisions	3	4	3	3	3
	Municipal and state support in case of calamity or danger	5	5	5	5	5
	Community leadership	3	3	3	3	3
Educational component	Lack of educational programs that provide information about their environment	4	5	5	4	4
	Collective or individual behavior in case of threat	5	5	5	5	5
Environmental component	Knowledge of the local reality facing problems	4	5	5	4	4
	Wastewater dumping	3	5	5	4	3
	Soil structure decline	3	5	5	4	3
	Latent pollution vectors	3	5	5	4	3
Institutional component	Institutions related to prevention and mitigation of natural disasters	5	5	5	5	5
	Training of technical personnel	5	5	5	5	5
SUM		113	127	126	119	113

3.4. Recommendations: Action plan according to the performed valuation

Once the factors influencing the vulnerability of the study sectors have been identified, preventive and corrective actions are proposed to mitigate or solve the current problem, which are described below:

3.4.1 Preventive actions. Through preventive actions, measures are proposed that allow the reduction of the urban vulnerability present in the human settlement, so a threat map (Figure3) and a vulnerability map (Figure4) were made. According to Figure3, it can be concluded that sectors S1, S4 and S5 have a high hazard level and sectors S2 and S3 a very high threat level. Similarly, Figure4 shows that all sectors have a high vulnerability.

3.4.2 Corrective actions. The corrective actions are used to correct the problem detected in the human settlement Colinas de La Provincia; their objective is to propose actions based on the different analyzed components that allow the reduction of the urban vulnerability present in it. Those actions are described in Table 3.

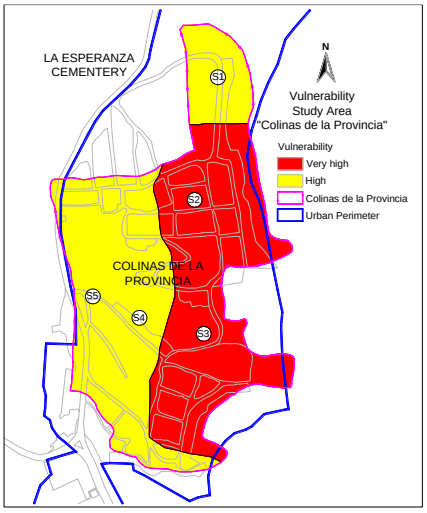


Figure 3. Hazard map.

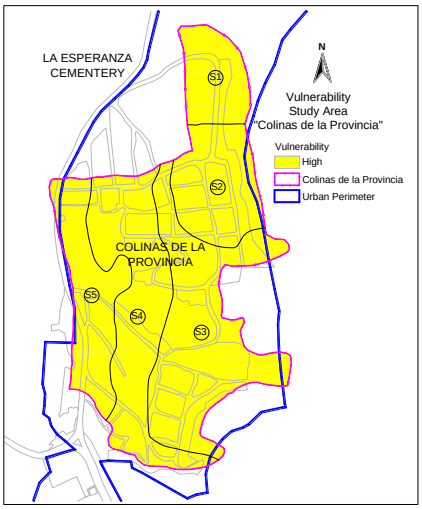


Figure 4. Urban vulnerability map.

Table 3. Corrective actions according to urban components for different study sectors.

Component	Corrective action
Physical	Relocation of houses located in dangerous hillside on the verge of collapse, in each sector. Improvement of the structural resistance of homes in the different sectors. Improvement and paving of roads.
Technical	Development of construction technologies for buildings and infrastructure in areas of greater vulnerability. Resource reserve in terms of equipment and machinery for emergency prevention and response.
Economic	Productive projects in the different sectors: Microenterprises, entrepreneurship and business development.
Social	Construction of communal hall. Construction of a Health Post.
Cultural	Presentations on community knowledge of vulnerability present in different sectors.
Political	Immediate public investment "manifest urgency" to improve current conditions of the different sectors.
Educational	Public entities that present educational programs in the sector on the subject of risk and disaster management.
Environmental	Management of a sewerage project in the settlement.
Institutional	Relationship of the settlement with institutions related to prevention and mitigation of natural disasters.

4. Conclusions

Vulnerability is the susceptibility of a community to suffer adverse effects, which in the urban context is identified as the probability that a city has to be affected by natural and anthropogenic phenomena, and its ability to face and overcome them [10]; on the other hand, the evaluation of urban vulnerability allowed the categorization of the study area, allowing to assess the vulnerability and present threats; in the threat assessment, it is concluded that sector one (S1), sector four (S4) and sector five (S5) present a high threat level, sector two (S2) and sector (S3) present a very high threat level what is due to the severity of them. In terms of urban vulnerability, it is high in all sectors and is due to the current settlement conditions. The preventive and corrective actions allow to diminish the urban vulnerability present in the sector.

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