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Vulnerability and resilience in the suburbs of Arvento, Cajititlan, in the face of global climate change effects

Vulnerabilidad y resiliencia en los suburbios de Arvento, Cajititlán, ante los efectos del cambio climático global

CARO-BECERRA, Juan Luis†*´, MAYORAL-RUIZ, Pedro Alonso´´, ROBLES-CASOLCO, Said´´´ and LUEVANOS-JACOBO, Jonathan Eduardo´

´Universidad Politécnica de la Zona Metropolitana de Guadalajara, Guadalajara, México.
´´Centro Universitario de Tlajomulco de la Universidad de Guadalajara, Guadalajara, México.
´´´Universidad Politécnica Metropolitana de Puebla, Puebla, México.

ID 1st Author: *Juan Luis, Caro-Becerra* / **ORC ID**: 0000-0002-3884-2188, **Researcher ID Thomson**: K-2859-2018, **arXiv Author ID:** juanluis74

ID 1st Co-author: *Pedro Alonso, Mayoral-Ruiz* / **ORC ID**: 0000-0002-5513-8678

ID 2nd Co-author: *Robles, Casolco-Said* / **ORC ID**: 0000-0003-1217-7682, **CVU CONAHCYT**: 122409

ID 3rd Co-author: *Jonathan Eduardo, Luevanos-Jacobo* / **ORC ID:** 0009-0008-2882-1800

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Abstract

In the Guadalajara Metropolitan Area (GMA), as in other parts of the world, the population lives in conditions of extreme poverty as a result of ineffective social and economic policies, which have led to a position of vulnerability to latent hazards: adverse weather events, natural or anthropogenic disasters, or a combination of these. On the other hand, resilience is relevant for local society, as it seeks to organize itself, provide services and response mechanisms in the territory in the face of hazards. The goal then, is to reduce the magnitude of the hydrographs by means of probabilistic and statistical models, which occur in the hydrographic basin. The results to be obtained were peak flow before and after urbanization, using the American Rational Formula. It is concluded that the construction of one or more hydraulic works will be necessary to solve the problem of possible floods.

Natural disasters, Hydrographs, Urbanization

Resumen

El Área Metropolitana de Guadalajara (AMG) como otras partes del mundo, la población vive en condiciones de pobreza extrema producto de políticas sociales y económicas ineficaces, han orillado a una posición de vulnerabilidad frente a los peligros latentes: eventos climatológicos adversos, desastres naturales, antrópicos o una combinación de estas. Por otro lado, la resiliencia es relevante para la sociedad local, pues busca como organizarse, dotarse de servicios y de mecanismos de respuesta en el territorio frente a los peligros. El objetivo entonces, es disminuir la magnitud de los hidrogramas mediante modelos probabilísticos y estadísticos, que se producen en la cuenca hidrográfica. Los resultados a obtener fueron gastos picos antes y después de la urbanización, utilizando la fórmula racional americana. Se concluye que la construcción de una o más obras hidráulicas será necesario para resolver la problemática ante posibles inundaciones

Desastres naturales, Hidrogramas, Urbanización

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* Correspondence to the Author (E-mail: juan.caro@academicos.udg.mx)
† Researcher contributing as first author.

Introduction

The water crisis is directly related to the adverse effects of Global Climate Change (UN-Water, 2019). The increase in the variability of the hydrological cycle has caused catastrophic consequences: floods in urban areas, prolonged droughts in the north of the country, forest fires with substantial losses of large areas of forest, as a result, the challenges are increasing to ensure that all humanity has access to basic water supply and sanitation services and that communities are more resilient and sustainable, as mitigation strategies to the GCC (Taiba, 2020).

In Mexico, as in other parts of the developing world, a large part of the population lives in conditions of extreme poverty, without even the minimum basic services of drinking water, sewer system and sanitation. This structural problem tends to affect mostly this sector of the population, when facing a situation of vulnerability to certain latent hazards, such as: adverse weather events, natural disasters or a combination of both (Cardozo, 2019).

Global Warming is an anthropogenic phenomenon that impacts the conditions and productive capacities of the soil, the availability of natural resources and their ecosystems (UNDP, 2009). This means lower agricultural productivity, since the scenarios indicate large losses of basic crops, as a result of prolonged droughts, reduced rainfall, water shortages and, as a consequence, higher temperatures which if we exceed the 2 °C threshold of water resources loss of ecosystems, health risks, coastal flooding and extreme weather conditions (IPCC, 2007).

As a consequence of the above, the melting of glaciers threatens water sources of urban populations, agriculture and hydroelectric production, as in other parts of the world it has caused mayor floods and reduction water flows in rives systems that are essential for food sovereignty.

On the other hand, vulnerability and resilience are conditioning factors to disasters, that is, they do not reach to analyze the causes of the hazard, but they are necessary to predict them (Cardozo, 2019).

The study of vulnerability and resilience should be analyzed from a holistic point of view, since the threat or hazard should not be separated from the causes that produce it. Both concepts are closely linked, since resilience is the capacity of the population to provide itself with services and response mechanism in the face of natural hazards and disasters, whether they are earthquakes, hurricanes or public health disasters such as the Sars-Cov-2 pandemic *(ibid).*

In the context we analyze vulnerability through its different variables, distribution and variability, presenting a case of study, the city of Tlajomulco of Zuñiga and its neighborhoods that compose it taking as a starting point elements of resilience: public transportation and vulnerability risks, hazards and insecurity.

Then the goal of this work is to generate new cartographic information of socio-environmental vulnerability from the management, this with the purpose of rethinking the changes of land use to the territory, opening of new urban developments, drinking water supplies, in addition to a new cartography related to extreme hydrometeorological events, which is the main cause of urban disasters, accurately representing the location of the sectors most vulnerable to disasters.

Background

The city of Tlajomulco has experienced significant growth since 2010 and accelerated growth since 2020, which has led to a change in land use that has cause significant alterations in natural runoff, causing a considerable increase in vulnerable points to flooding, resulting in a decrease in water infiltration into the aquifers.

The vast majority of the neighborhoods and subdivisions are areas vulnerable to flooding and natural disasters, the main cause is still the agricultural practices called slash-burn, water scarcity, mainly due to urban sprawl, as it implies no Territorial and Ecological Planning.

Based on the censuses by the National Institute of Statistics and Geography (Inegi, 1990, 2000, 2010) the population density of Tlajomulco has been above the Guadalajara Metropolitan Area (GMA) with growth rates in the order 12.92%, while at the metropolitan level they oscillate between 2.12% respectively.

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As we noted above Tlajomulco of Zuñiga, by 2015 had a population of 549,442 inhabitants (Inegi, 2015), which would be equivalent to 11.2% of the total inhabitants of the GMA, as shown in table 1 and 2.

Town size	1990 localities	1990 Population	2000 localities	2000 Population	2010 localities	2010 Population
1 – 99	166	1,661	203	3,362	221	8,651
100 – 999	16	7,649	8	2,624	8	5,201
1000 – 1999	7	9,672	11	16,820	16	28,732
2000 – 4499	4	23,773	3	18,851	7	24,721
5000 – 9999	3	23,773	3	18,851	9	66,780
10000 - 14999	1	11,567	3	42,958	5	60,492
15000 – 19999			1	16,177	5	135,114
20000 - 99999					1	86,935
totals					272	416,626

Table 1 Evolution of the growth of localities by population size in Tlajomulco of Zuñiga, Jalisco
Source: INEGI (1990, 2000, 2010)

Localities greater than 10,000 inhabitants	1990 location	1990 inhabitants	2000 location	2000 inhabitants	2010 location	2010 inhabitants
Hacienda Santa Fe					86,935	22,821
San Agustin			14,355	3046	30,424	7390
Tlajomulco	11,567	2,215	16,177	3099	30,273	7085
San Sebastian			13,908	2861	30,273	6263
Sta. Cruz del Valle				2799	26,866	5671
Lomas del Sur					19,413	5016
Real del Valle					13,949	3701
Lomas de San Agustin					11,836	2936
Villas de la Hacienda					11,078	2800
La Tijera					12,425	2796
Sta. Cruz de las Flores					11,204	2869
Totals	11,567	2215	59,135	11,795	282,541	69,148

Table 2 Evolution of growth in Tlajomulco of Zuñiga
Source: Hernández García, 2020

State of the art

According to Pesaresi *et al,* (2017) on a global scale 2700 million people are vulnerable to earthquakes, about 1000 million to floods and 414 million are exposed to the eruption of volcanoes.

Latin America and the Caribbean, only in the last ten years, natural disasters have exceeded the number of 4500 people dead, 62 million people affected with total losses of their domestic and material goods, numbers only surpassed by Asia (UNDRR, 2015). These geographic, geological, geomorphological and meteorological conditions expose the American continent to natural hazards, coupled with an unsustainable increase urban poverty, social inequalities, environmental degradation, but above all the lack of implementation of Land and Ecological Planning with a focus on risks and disaster in the management or urban watersheds (Alcantara-Ayala, 2019).

On the other hand, the concept of resilience in the last 20 years has focused on Risk and Disaster Reduction (RDR), being even accepted by the United Nations Organization (ONU) (Bocco, 2019) and have even become the new paradigm of RDR management (Manyena, 2006).

Vulnerability and resilience

The risk-disaster process goes beyond concepts, meanings and emphases of vulnerability, adaption and resilience (Bocco, 2019), while RDR has been contextualized spatial terms, either: a) to quantify and damage of a physical system, b) fragility and damage of built environmental and c) losses of socioeconomic systems (Bobrowsky, 2013).

On the other hand, the beginning of the 21 st century resilience is the response and recovery from a disaster to material damage (Kendra, et al, 2018; Macias, 2015). While for the (UNISDR, 2015) resilience is conceived as the capabilities of a system exposed to a hazard of natural origin, in order to recover effectively, to achieve the restoration and improvement of structures.

However, (Norris *et al,* 2008) encompass the concept of resilience under three aspects.

a) Engineering sciences: it is the resistance capacity of a material to return to its original state, including the speed with which a body maintains its equilibrium after displacement.

b) Sustainable development sciences: it is capacity to maintain an ecosystem without changing its original structure, in other words, it is the capacity to adapt to a complex system.

c) Socio-ecological sciences: the capacity of individuals and communities to resist and recover in the context of adverse experiences.

Materials and methods

Case study: Arvento subdivision, one of the most inappropriate places in the Guadalajara Metropolitan Area (GMA) and susceptible to flooding.

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Due to the fact that the morphology of the Arvento subdivisions is an irregular polygon, whose design obeys of natural elements, such as its relief, as well as the bodies of water that cross it, its subdivisions are practically buildings that have regular shapes with orthogonal tendencies, as show in figure 1 and 2.

Figure 1 Orthogonal construction in Arvento subdivision
Source: Muñoz, 2023

The Arvento subdivisión currently makes up the northern part of the town of Cajititlan, north of Chapala lake, its geographic coordinates are 20° 26' north latitude and 103° 18´ west longitude. Its surface area is approximately 289 acres, based on the last census of 2020 and the National Institute of Statistic and Geography (Inegi, 2020) indicates that of the 5165 built homes, 3350 are only inhabited.

Figure 2 Public areas and urban equipment
Source: Muñoz, 2023

The public areas and the existing urban equiment are concentrated in the central part of the subdivisión, where the "Arvento-Cajititlan" truck terminal is located to the south is the Polytechnic University of the Metropolitan Zone of Guadalajara, the only education center in the subdivision, as the shown in figure 3.

Figure 3 Façade of the Polytechnic University of the Zone Metropolitan Area of Guadalajara
Source: Caro, 2023

In methodological terms, this work articulates elements of information from Citizen Participation Action (CPA). For this purpose, interviews and questionnaires on housing development and type of housing connections of main roads in urban transportation, fundamental in the generation of information, were used.

The direct participatory of the research is of utmost importance, since the participation in community assembles, participation in aid campaigns for the victims, to mention just a few, were of great relevance. Finally, to validate the cross information criteria, intra method triangulation was incorporated (Given, 2008) by using different qualitative data techniques, mainly institutional reports and written press.

The findings of information on the people interview regarding housing prices were the following: in the Arvento subdivision people were interview who paid $390,000.00 for housing, in addition it was identified that a person given his work activities, allowed to identify a pattern of material values and income level of its residents according to their location within the subdivisions, which as noted Arvento has an elongated shape of 2.5 km long.

The interview detected that people perceived purchasing power living near the main access roads to the subdivision, as opposed to residents living in homes more than 3 km away from the main access roads, which implies a decrease in the rental value of housing, with respect to those located near the main roads.

It should be noted that the Arvento subdivisions was promoted by Geo Houses as an area close to the Cajititlan lake, where housing could be purchased at affordable prices.

American Rational Formula

The American Rational Formula is one of the most widely used for estimating the maximum flow associated with a given design rainfall. It is normally used in the design of both urban and rural drainage works, and also has the advantage of not requiring hydrometric information for the determination of extraordinary peak flows (Breña-Puyol, 2006).

Most of the empirical methods have been derived from the American Rational Method, the first to apply it was Kuichling (1989). However, other authors cite that the basic principles of this method were developed by (Mulvany,1951).

The American Rational Formula equation is as follows:

$$Qp = 0.278\ c\ i\ A \quad (1)$$

Where:

C = runoff coefficient in natural terrain = 0.20

C = runoff coefficient in urbanized area = 0.85

i = rainfall intensity = 57.91 mm/hr

A = area of surface to be projected = 193.97 acres ≈ 0.785 km^2.

Results and discussion

Tlajomulco of Zuñiga is one of the municipalities with the highest population growth in the country, with an explosive demographic expansion in recent decades, between 2005 and 2010 alone, the population increased by 293,007 inhabitants (Inegi, 2010).

A significant proportion of this population lives in the micro-watershed of the Arvento subdivision, 3349 homes are occupied, as noted above.

Growth and land use and change, a product of ineffective policies in the GMA has impacted the Arvento micro-watershed, decreasing soil permeability and altering the *precipitation-infiltration-runoff* relationship, causing a significant impact on hydrological functioning and therefore an increase in vulnerability due to flooding of human settlements (De Alba Martinez, 2019).

Tlajomulco of Zuñiga, the agricultural extractivist model has played a central role in the vulnerability of production, intensifying environmental risk due to the near disappearance of native corn species.

We understand extractivism as those productive activities of territorial dispossession that occupy large extensions of communal property, seriously affecting the original populations, in pursuit of progress (Alimonda, 2016).

Regarding susceptibility, understood as the measure of how much it is affected based on its demographic characteristics (Cutter, 2013), Arvento presents particular qualities of social vulnerability, since poverty in the region is above the average for the state of Jalisco with 23.8 % (IIEG, 2023), ranking fourth with the lowest working poverty in the country (ibid).

Exposure is understood as the degree of spacing in which a group of people could be affected by a hazard (Birkmann, 2013). Due to its geomorphological location, the municipality of Tlajomulco has experienced at least 102 points with increased risk of flooding, mainly in area near Primavera forest, due to erosion processes in the upper parts, subdivisions that were built on stream or land that functioned as regulating crystals, identified in the Risk Atlas of Tlajomulco as points with a high probability of flooding (Melendez, 2020).

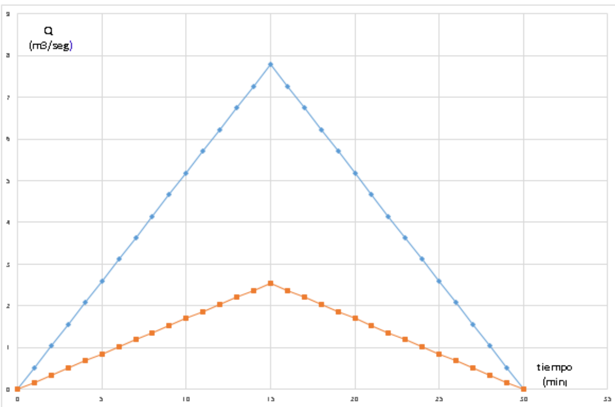
The results obtained were the peak flow discharges before and after urbanization, as well as their Triangular Unitary Hydrographic (TUH) graphs, both for peak flow and their retained volume.

For natural land:

$$Qp = 0.278 * 0.20 * 57.91 * 0.785 = 2.527\ m^3/seg$$

And for urbanized land:

$$Qp = 0.278 * 0.85 * 57.91 * 0.785 = 10.74\ m^3/seg$$



Graphic 1 Triangular Unitary Hydrographic, before and after urbanization
Source: Caro, 2023

Conclusions and recommendations

The population density of Tlajomulco of Zuñiga has grown at an accelerated rate, with growth rates of 12.9 % well above the average for GMA, since the population tripled in the last 10 years from 123,619 to 416,626 inhabitants.

This growth has marked two types of settlements, the first consist of urban localities with a high population with concentration and with access to the GMA, while the second are localities and settlements far from the urban sprawl, their current state presents irregular and discontinuous forms, as is the case of subdivision Arvento, thus identifying a relationship between spatial variables of dispersed urban sprawl.

It should be borne in mind that in areas where the stream overflows (plains and valleys), when the ordinary maximum flow peaks through the section of the river under study, it can overflow and invade a large area of surrounding land. In this case, the channel delimitation will be up to the margin of the channel marked by the ordinary floods without flooding and from this point on, the federal zone will be established.

The main problem continues to be, as we have already pointed out, bad management of rainwater during the rainy season, the separate drainage systems and infrastructure of regulating crystals and existing channels in the basin have been insufficient. This problem is caused by a inefficient integration policy, especially when changes in land use are authorized and large extensions of protected natural areas begin to be urbanized, as is happening in the valley zone of Tlajomulco of Zuñiga.

As recommendations, a clear awareness of the importance of water management should be acquired, since on the one hand they reduce the water shortage suffered by most of the population, and the other they prevent large volumes of water from being wasted.

In order to detain water, there are various types of works and practices such as: level trenches, staggered dams, absorption wells and others that allow the storage of a good part of the rainwater for later use.

It is essential that these actions for the storage of surface and subway water be carried out rationally and systematically throughout the sub-basin, and at the same time, that exhaustive reforestation be carried out.

With all of the above, it can be observed that, if we want to have more water, it is necessary to detain and harvest it with adequate works, so that most of the precipitation can be detained and infiltrated or conducted to the available storages.

In addition to the conduction of rainwater to available surface storages, such as lagoons, lakes and others, the recharge of aquifers is a recommendable practice since it solves several problems such as reducing evaporation, avoiding floods, reducing floods and the disasters they cause, reducing water erosion and avoiding the silting of dams, bodies of water, farmland and populations in vulnerable areas.

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