Applied methodologies to the Earth Sciences

Ignacio Mora González
Coordinator

Applied methodologies to the Earth Sciences

Ignacio Mora González
Coordinator

Applied Methodologies to the Earth Sciences

Coordinator

Ignacio Mora González

First Edition, 2015

511 Adolfo Ruiz Cortinez Ave.
Francisco Ferrer Guardia
91020 Xalapa Veracruz
Mexico
Edimpa.arana@hotmail.com

Cover Picture: Sergio R. Rodriguez Elizarraras
Compilation and Editing: Irma Hernández Contreras
Typewriting and technical support: Clara Martinez Mora
English Version: Marisol Ruiz Barradas

ISBN: 978-607-9091-49-1

Printed in Mexico

CONTENT

The Earth Sciences focus on the greatest challenges facing humanity in the twenty-first century, as they are aimed at producing knowledge related to the welfare and protection of man on Earth. The Earth Sciences integrate both natural and anthropic phenomena, which combine the multidimensionality of physical, chemical, biological, ecological, social and economic processes and factors.

In addition, the increasing complexity in the context of both natural problems on the planet and those arising from the interrelation of man and/or society with the environment, makes it necessary to develop methodologies that allow analyzing, measuring, evaluating, understanding and explaining multiple aspects of the phenomena that are happening in different regions and territories of the country and within the global context. Thus, the Earth Sciences aim to propose possible solutions with relevance and social and environmental rationality.

The methodologies in the field of the Earth Sciences, which are presented in this book, comprise a wide range of topics, which assure within the scientific field, a wealth in terms of addressing the phenomena. They offer the opportunity to propose certain solutions, as well as support for the formulation of policies and strategies that can be socially useful. In this way, the variety of topics presented (the estimation of the risk by natural phenomena; urban microzoning for land use planning and risk management; the estimation and monitoring of danger and urban seismic risk; the mass wasting by geological and hydrometeorological phenomena; the integral management of watersheds; the geography of the landscape for disaster management; the relevance of greenhouse gas emissions) among others, integrates several innovative methodological approaches that together enrich the subjects of study and the various disciplines and specialties related to the phenomena studied in the Earth Sciences.

CHAPTER 1

Modeling in risk estimation from natural hazards

Eduardo Reinoso
Mario Ordaz
Mauro Niño
Benjamín Huerta

Abstract

This chapter presents the advancements made in the modeling for risk estimation in the infrastructure subject to the action of natural phenomena such as: earthquakes, hurricanes or floods. Taking into account quantitatively, through mathematical models that describe these phenomena, the characteristics necessary to estimate their intensities and their annual exceedance rates, in the same way, it is estimated the damage that the infrastructure could suffer as well as a percentage of its replacement cost, considering its main structural and geometric characteristics. To achieve this, geographic information systems and ad hoc computer programs are used to estimate the hazard through indicators such as the expected annual loss or the maximum probable loss. Hazard modeling is an important and powerful tool whose results serve as a basis for designing and implementing strategies that help create vulnerability reduction programs, territorial planning, emergency response and preparedness plans, or reconstruction programs. so that the response capabilities to the occurrence of a natural phenomenon are not exceeded.

Introduction

The catastrophic socioeconomic impacts suffered during the last decades as a result of disasters caused by natural phenomena, not only in our country but around the world, indicate the high vulnerability of human settlements (rural and urban), and the deficient levels of financial and social protection that are implemented to cover the cost of associated economic and human losses.

A key element for the sustainable development of any region is the knowledge of the existing hazard and the causes that generate it, in such a way that different plans and strategies can be developed aimed at the prevention and mitigation of the damages caused by natural phenomena. For this, it is important to know, in as much detail as possible, the three components that define a risk: hazard, exposure and vulnerability.

The Institute of Engineering from the Mexican University UNAM (due to its initials in Spanish) has developed a large number of models that serve to define, in a georeferenced manner, not only the intensity of the different events produced by natural phenomena such as earthquakes, hurricanes, floods or landslides, but also, to characterize the behavior of the different infrastructure that can be located in a study region and estimate, in probabilistic terms, the hazard generated. These models have been implemented in tools that are already in operation such as R-FONDEN (World Bank, 2012a), a tool used by the Ministry of Finance and Public Credit

(SHCP in Spanish) to carry out the risk transfer of public infrastructure , or the CAPRA platform, an initiative promoted by the World Bank (2012b) to estimate risk through standardized methodologies that help in making hazard management decisions in different countries around the world.

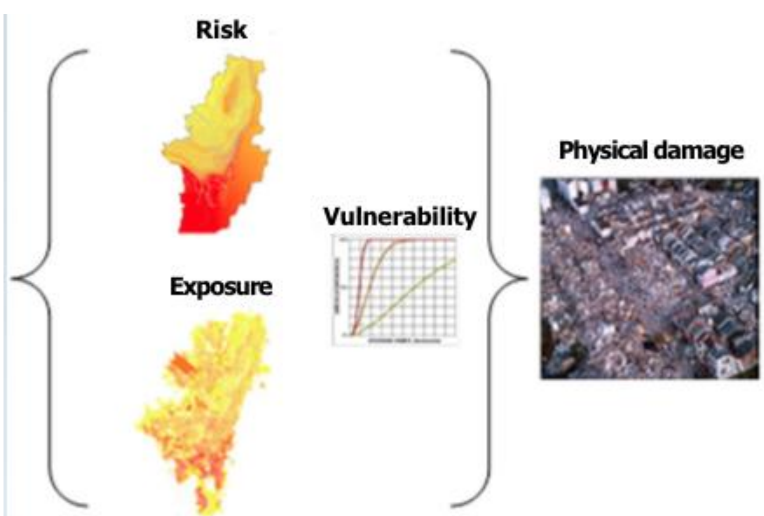
Risk modeling is an important and powerful tool whose results serve as a basis to design and implement strategies that help countries, states or municipalities to carry out vulnerability reduction programs, territorial planning, response plans and preparation in the case of emergencies or reconstruction programs, in such a way that their response capacities in the event of a natural phenomenon are not exceeded.

Probabilistic risk model

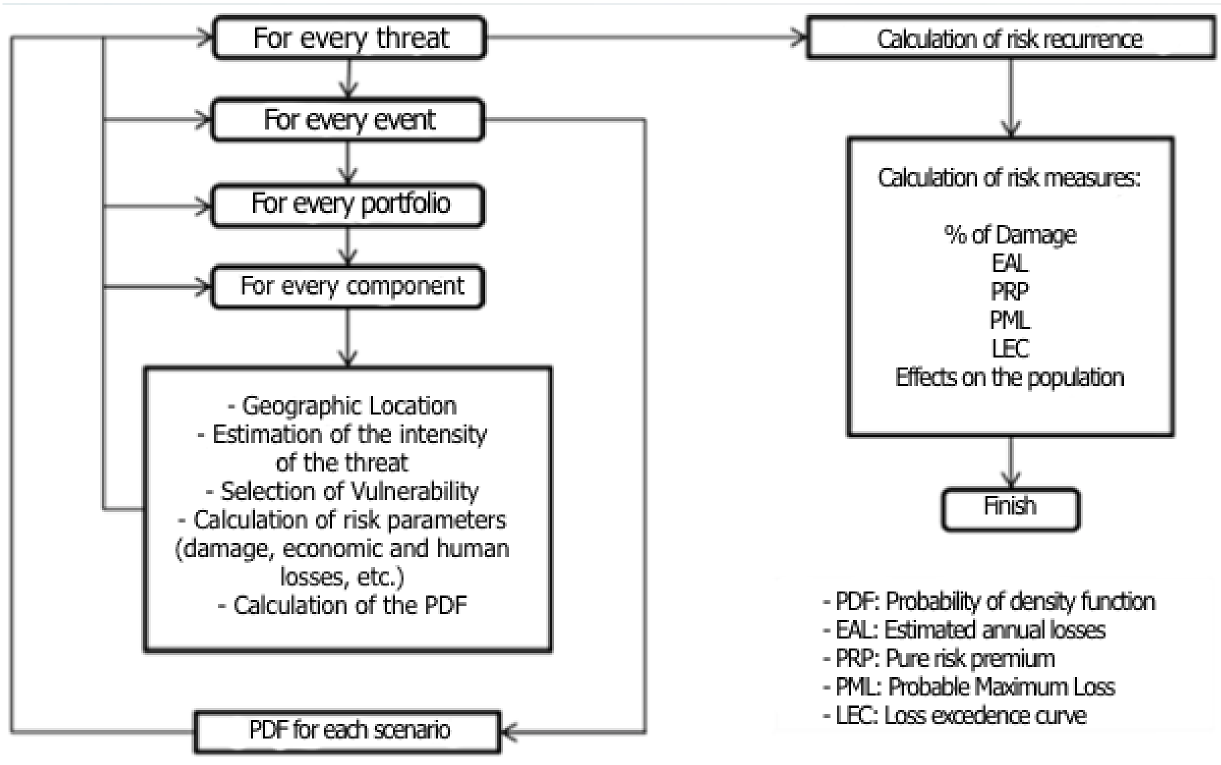
Currently there is a limited amount of data and historical information about catastrophic events, due in some cases to the low occurrence of low-frequency disasters, and in others, to disasters with a short and recent temporary window. Considering the possibility of presenting highly destructive future events, the estimation of risk should focus on probabilistic models, which allow using the scarce information available to predict possible catastrophic scenarios, in which the high uncertainty involved in the analysis is considered.

Considering the large uncertainties associated with the estimation of the severity and frequency of recurrence of natural disasters, the risk assessment is based on probabilistic formulations that incorporate uncertainty in the estimation of risk.

Estimating disaster risk means estimating the damage in the different populations and assets exposed in places of interest, calculating their vulnerability to specific phenomena (natural or anthropogenic) and obtaining the probability and intensity with which one of these phenomena occurs. Through the combination of these parameters, it is possible to obtain a quantitative value of the assets at hazard for an expected danger or hazard. The quantitative risk estimate is expressed in economic terms or number of deaths or injuries. For this, reliable input data are required, also defined in quantitative terms. The main input data for risk estimation are: hazard, exposure and vulnerability (Figure 1).



As a result of the risk analysis, Figure 2 summarizes the procedure for the probabilistic estimation of risk and its different measurements.



Hazard Modeling

The hazard associated with a natural phenomenon is measured by the frequency of occurrence and the severity measured by some hazard intensity parameter determined at a specific geographic location. The hazard analysis is based on the historical frequency of events and the severity of each one. Once the hazard parameters are defined, it is necessary to generate a set of stochastic events that define the frequency and severity of thousands of events, thus representing the main parameters of the hazard in the region. The hazard analysis generates values of the intensity parameters defined for each of the hazards studied and for each one of the stochastic events, through the analytical modeling of each of the phenomena.

To achieve this hazard modeling, a series of probabilistic analytical models have been developed for the main natural phenomena such as earthquakes, hurricanes, heavy rains, floods, landslides and volcanic eruptions. As shown in table I, each of these phenomena of nature produces different types of hazards, so the events that can trigger a disaster must be specifically considered.

Table 1 Phenomena and Hazards

Natural phenomenon	Hazard
Earthquakes	Ground movement
	Tsunami
	Mudslides
	Liquefaction
Volcanic Eruptions	Fall of Ashes
	Lava Flow
	Lahar
	Pyroclastic Flow
Tropical Cyclone	Wind
	Storm Surge
	Flooding
	Mudslides
	Sinkings
Storms, freezing waves, tropical waves	Hail
	Snow
	Winds
	Storm Surges
	Flooding
	Mudslides
	Sinkings

The main objective of the probabilistic hazard analysis is to provide the necessary information of hazards in order to reliably calculate the different probabilistic parameters related to the losses and effects of the different natural phenomena, for different periods of return in the range between 10 and 1000 years whenever possible, although longer periods may be used in certain specific cases such as volcanic eruptions.

For each one of the hazards, a set of stochastic scenarios is constructed, each one qualified with its frequency and severity, based on the best available information as well as on the general opinion of experts in the different fields.

The result of the hazard assessment is a database for each of the hazards studied that contains a set of stochastic events, characteristic of the total hazard, mutually exclusive and collectively exhaustive, corresponding to all the possible hazard scenarios that they can appear in the region. Each of the hazard analyzes shows a geographical distribution in a given area of influence of particular intensity values.

Another way to represent the hazard is through curves that represent, for a specific site, the expected intensity of a given event (maximum acceleration of the ground, wind speed, water stress, etc.) associated with a return period or its inverse, an exceedance rate.

Seismic Hazard

Researchers at UNAM's Institute of Engineering have been working for several years in the modeling of seismic hazards, as a result the following methodology is proposed for the definition of seismic hazard that includes the following steps:

1.- Definition and characterization of the main seismogenic sources based on geological and geotectonic information.
2.- Definition of seismicity parameters to the different seismic sources. These parameters will be used to define the possible occurrence of future seismic events, through a Poisson process (equation 1) or using the characteristic tremor model (equation 2).

$$\lambda_i (M) = \lambda_{0i} \frac{e^{-b_i M} - e^{-b_i M_{ui}}}{e^{-b_i M_0} - e^{-b_i M_{ui}}} \quad (1)$$

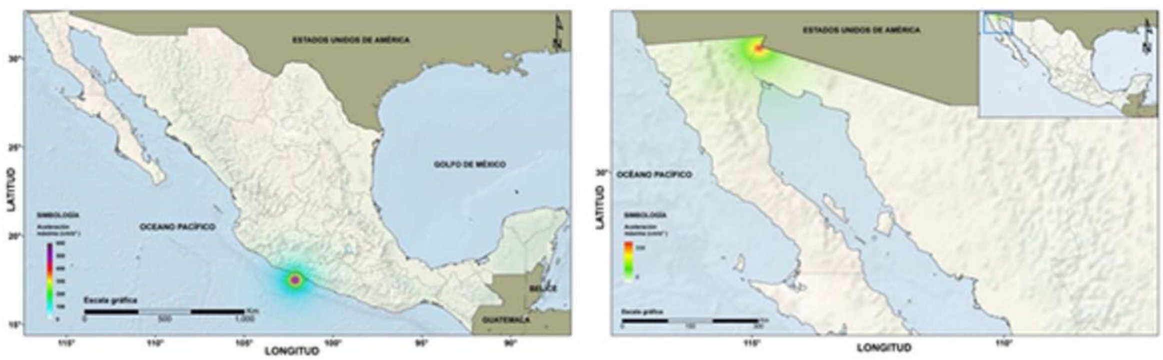
Where, M_0 is the minimum relevant magnitude, taken as 4.5 in this study; λ_{0i}, corresponds to the average number of events per year of earthquakes with magnitude greater than 4.5 that occur in a given source; b_i is the slope of the initial stretch of the magnitude recurrence curve; M_{ui} is the maximum magnitude that can be generated in each source and is estimated based on the maximum possible break length of each of the sources and other morphotectonic characteristics

$$\lambda(M) = \lambda(7) \left[1 - \Phi\left(\frac{M - EM}{\sigma_M}\right)\right] \quad ; \quad M > 7 \quad (2)$$

Where λ (7), *EM* and σ_M are parameters that must be obtained statistically for the Mexican zone of subduction, and ϕ is the standard normal distribution function.
These parameters, different for each source, define the exceedance rate of each of the seismic sources, and are estimated by means of Bayesian statistical procedures (Rosenblueth et al., 1989, Ordaz et al., 1995) that include information on regions tectonically similar to those of the country (through information validated by experts), especially on the value of M_{ui}.

3.- Generation of a set of stochastic events compatible with the distribution of location, depth, frequencies and magnitudes. For each defined source, a series of scenarios of different magnitudes are generated, whose probabilities to occur are calculated based on the specific magnitude recurrence curve of that source.
4.- Attenuation of terrain movement parameters based on attenuation laws that best represent the conditions of movement between the sources and the sites where the threat is calculated, whether existing laws in the literature or created with local data information.
5.- Generation of threat maps of representative events with a spatial distribution of seismic intensity (spectral values) for each event. Figure 3 shows peak ground accelerations (PGA) for two simulated seismic events, figure 3a corresponds to the PGA of a subduction earthquake on the coast of Guerrero with a magnitude equal to 8.2 and

Figure 3b shows the PGA of a simulated earthquake of magnitude 7.2 in the northwest region of the country due to the San Andreas Fault.



a) PGA for an 8.2 Mw earthquake b) PGA for a 7.2 Mw earthquake

Figure 3. Map of seismic intensities

6.- Modification of threat parameters by site effects since the dynamic response of soil deposits modifies the characteristics of the movement in amplitude, frequency content and duration causing effects of increase and decrease in intensity. With the information obtained, the maps calculated in step (5) are modified directly.

7.- Application of the probabilistic model of seismic threat to obtain seismic hazard maps for different return periods. The threat *v*(Sa), expressed in terms of the exceedance rates of intensities Sa, is calculated by the following expression

$$v(Sa) = \sum_{\mathrm{i=1}}^{\mathrm{N}} \int_{M_0}^{M_{ui}} -\frac{d\lambda\,(M)}{dM}\; Pr\left(SA > M, R_i\right) dM \quad (3)$$

where the sum encompasses the totality of the seismic sources *N*, and *Pr (SA>Sa|M,*R_i*)* is the probability that the intensity exceeds a certain value given the magnitude of the earthquake, *M*, and the distance between the *i*th source and site, R_i. The functions *λi (M)* are the activity rates of the seismic sources. The integral is carried out from M_0 to M_{ui}, which indicates that the contribution of all the magnitudes is taken into account for each seismic source. In Figure 4, (missing) seismic hazard maps are presented for different return periods obtained by applying the methodology mentioned above.

Wind hazard

In the last decades, in the regions affected by the influence of tropical cyclones, many efforts have been invested to find some numerical models that allow to determine the coastal conditions when they are being affected by the presence of hurricanes, being those of the parametric type those that have been more successful on this task.

The parametric models of pressure and wind depend on the following information: position of the eye of the hurricane, central pressure, maximum wind speed sustained in the eye of the hurricane and radio-cycle, also known as radius of maximum gradient. All these parameters can be found in climatological bulletins, with the exception of the cyclic radio, that can be determined using the following expression (Silva et al., 2002):

$$R = 0.4785Po - 413.01 \quad (4)$$

Where *R* is the cyclostrophic radius in kilometers and *Po* the central pressure in millibars.
A parametric model of tropical cyclones used to estimate hazard was developed by Silva et al. (2002), which is composed of the pressure and wind submodels. The pressure model is represented by the following connection:

$$Pr = Po + (P_N - Po)e^{-R/r} \quad (5)$$

where *Po* is the pressure at the center of the hurricane, *Pr* is the pressure at a radial distance, r in km, P_N defines the normal pressure and is equal to 1013 millibars and *R* is the radius of maximum cyclostrophic winds. On the other hand, the wind speed evaluated at ten meters above sea level, in km / h, for a cyclone in motion and for a distance *r* measured from the center of the cyclone, is given by:

$$W = 0.886[F_v U_R + 0.5V_F \cos(\theta + \beta)] \quad (6)$$

where *W* is the wind speed sustained at 10 meters above sea level, V_F is the velocity of displacement of the hurricane, (θ + *β*) is the angle formed by the direction of displacement of the cyclone and a point at a distance *r*, $F_v = U_r / U_R$ is the ratio of the wind speed to a radial distance *r* and the maximum wind gradient.

In addition to the above, the expression proposed in the civil works manual (CFE, 1993) is used to calculate wind speeds for a location on land. Figure 5 shows a map with expected values of maximum wind speeds for a hurricane similar to Hurricane Emily, occurred in 2005.

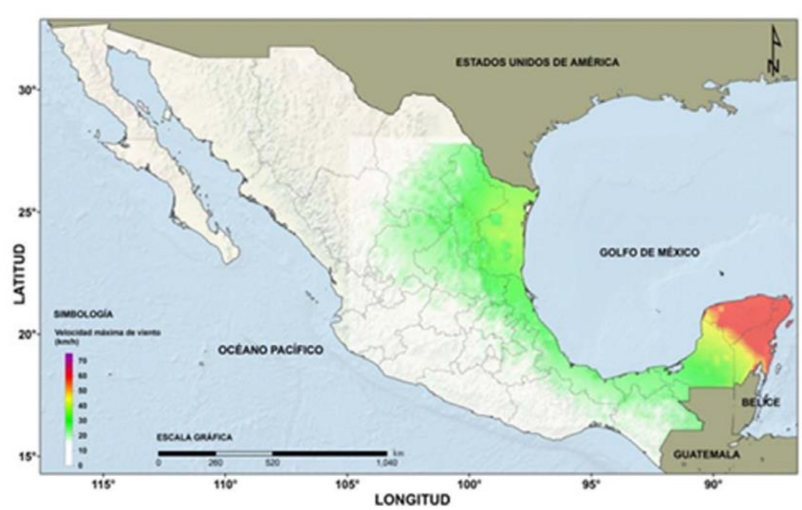


Figure 5. Maps of maximum wind speeds for a hurricane like Emily (2005).

Flood hazard

Methodologies for the estimation of flood spots due to intense precipitation have also been developed at the Institute of Engineering. The proposed methodology is summarized in the following steps:

1. **Estimation of precipitation scenarios based on historical records:** Using the objective analysis methodology shown in Vázquez (2000) and Méndez (2010), regular precipitation meshes are obtained (digital models in grd format) from an initial field , which is modified successively by a function that ponders the information available in the climatological stations near the study site within a specified radius of influence. Initially, the assimilated data set known as the North American Regional Reanalyses (NARR) will be used as initial field (Mesinger et al., 2005).
2. **Estimation of the probability of occurrence of the historical scenarios:** Starting from digital maps of isohyets of the country associated with different periods of return for a duration of 24hrs an interpolation process is carried out in which the return period for each one of the precipitations considered is determined pixel by pixel in such a way that in the end the return period to which the evaluated precipitation mesh is associated is determined. The exceedance probability of the scenario *k* will be equal to the multiplication of the exceedance probabilities of the intensities and y_i in the pixel *i* as shown in the following equation:

$$Pr\ (k) = \prod_{i=1}^{N_{pixels}} Pr(y_i) \quad (7)$$

3. **Calculation of the average precipitation per scenario for each of the basins:** For the sub-basins under study, the average precipitation associated with each rainfall scenario is determined through the use of tools and programs that facilitate the manipulation of Geographic Information Systems. The procedure consists of determining what is the average precipitation that is within the sub-basin under study.
4. **Calculation of runoff volumes associated with precipitation scenarios for the analyzed basins:** By using the American rational method, runoff volumes are determined for each of the sub-basins analyzed. In order to achieve this, information of the properties of the sub-basins (watershed, area, main channels, slope, time of concentration, etc.) is used.
5. **Estimation of flood areas for each rainfall scenario:** To estimate the flood areas corresponding to the different precipitation scenarios, Volume-Elevation curves are prepared for each of the sub-basins in which the study areas are divided. To know the water depth at a given location, only the difference between the flood elevation and the natural elevation of the land at the desired point is obtained. This procedure accumulates the volume of water from the lowest areas to the highest of the analyzed basins.

To carry out the last step, LIDAR technology is used, which allows laser measurements of the topography of a place from an aircraft, providing three-dimensional information about the shape of the Earth's surface. The definition that is reached through this technology allows to obtain details about trees, shrubs, buildings, among others.

Once the relationship between the elevation and the flood volume for each sub-basin is known, the estimated runoff volumes are used for each of the proposed scenarios and the elevation of the associated water surface is extracted. In figure 6 one can see an example of a flood map, using the methodology described. As expected, the deepest flooded areas will be generated in the lower areas of each sub-basin.

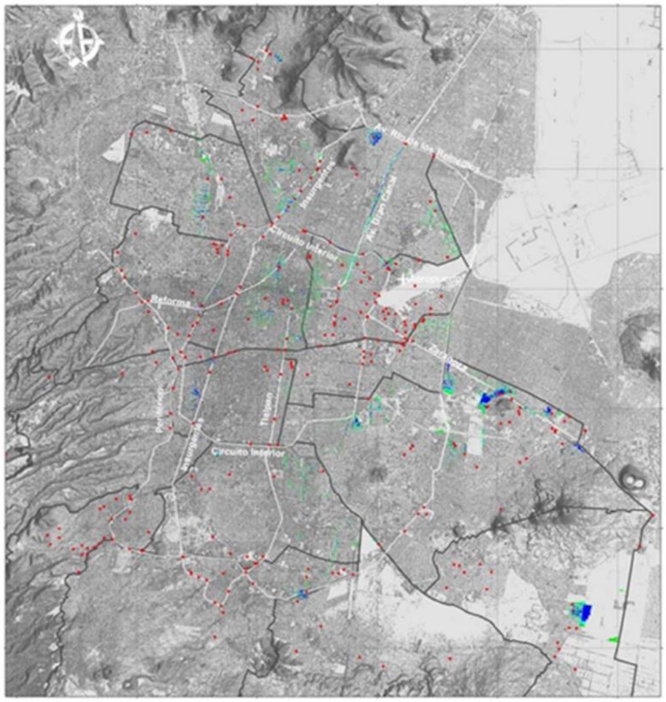


Figure 6. Example of flooded areas using LIDAR technology.

Characterization of the exhibition

The exhibition mainly refers to infrastructure components or to the exposed population that may be affected by a given event. To carry out the characterization of the exhibition, it is necessary to identify the different individual components, including their geographical location, their geometrical, physical and engineering characteristics, their vulnerability to the threatening event, their economic value and the level of human occupation that can be reached in a certain analysis scenario.

Exposure values of goods at hazard are estimated from secondary information sources such as existing databases or can be derived by means of simplified procedures based on general social and macroeconomic information, such as population density, construction statistics or more specific particular information. Based on the available information, an exposure database is created, constructed in a geo-referenced manner, where all the specific information required for the analysis is included.

On the other hand, a series of useful tools can be used to gather information from satellite images, aerial photographs or directly through field visits. These tools allow the creation of georeferenced databases with some basic characteristics such as construction type, area and number of floors, which can then be complemented with statistics of the area, with previous zoning of the building types in the city or through direct field observations
The analysis should generally include all physical assets subject to hazard for any of the aforementioned threats.

The assets include the main infrastructure types:

- Buildings
- Houses
- Industrial facilities
- Roads and roads
- Bridges
- Electrical system including generation, substations and transmission
- Communications system
- Piping systems (potable water, sewerage, oil pipelines, gas pipelines, etc.)
- Tunnels
- Dams
- Nuclear plants

Cost of reconstruction

The cost of reconstruction is an important input for the definition of hazard estimators. The value includes both the value of the good as such (main structural and non-structural elements) and the valuation of contents susceptible to damage. For example, in the case of floods, damages are usually associated with the contents and with a portion of the structure that requires repair and maintenance after the disaster has occurred.

Vulnerability modeling

The characterization of the vulnerability is done by generating functions that relate the damage level of each component with the intensity of the threat phenomenon. The vulnerability function must be estimated for each of the characteristic construction types, so that they can be assigned to each of the components of the exposure database. By means of the assigned vulnerability functions it is possible to quantify the damage or affectation produced in each of the assets before the action of a given event, characterized by some of the intensity parameters. Each vulnerability function is characterized by a mean value and a variance with which it is possible to estimate its respective probability function.

In general, vulnerability functions are defined using one or more of the following types of information:

- Analytical models.
- Laboratory tests.
- Statistical data.
- Expert opinion.

The following is a description of how to obtain vulnerability functions for the seismic threat.

Seismic vulnerability

Expected damage

In the methodological development presented below, the seismic intensity is measured mainly through the spectral acceleration and the behavior of the structure is defined in terms of the maximum distortion of the story, since it is considered as the parameter that best reflects the damage that the structure could suffer from such intensity (BSSC, 1997, Bertero et al., 1991, Priestley, 1997, Sözen, 1997).

Considering that the damage is expressed in general in terms of the maximum distortion of the floor, it is necessary to transform the vulnerability functions so that they are expressed in terms of the parameter required by the threat. In addition, the inelastic behavior of the structure must be considered for its estimation, for which it is necessary to resort to some approximate method of inelastic calculation of structural seismic response.

To achieve the above, the capacity spectrum method is used (Freeman, 1975, ATC-40, 1996) to define the inelastic behavior of the structure and the expressions proposed by Miranda (1999) to define the maximum distortion of the floor space associated with the lateral displacement of the structure, where, from the spectral acceleration it is possible to determine the maximum distortion of the story with the following expression:

$$\gamma_i = \frac{\beta_1 \beta_2 \beta_3 \beta_4 T^2}{4\pi^2 N h} Sa(T) \quad (8)$$

where, β_1 is the relationship between the maximum lateral displacement at the upper level of the structure and the spectral displacement, considering a linear elastic behavior model, β_2 describes the relationship between the maximum distortion of the story and the overall distortion of the structure, which it is defined as the maximum lateral displacement in the roof divided by the total height, β_3 expresses the relation between the maximum lateral displacement of the inelastic behavior model, and the maximum displacement of the linear elastic model, β_4 is the factor that considers that the distribution of the lateral load with the height is different in the elastic and inelastic model (Miranda, 1997), h is the height of each floor of the structure, *N* is the number of stories and Sa (T) is the spectral acceleration, which depends on the fundamental period of vibration, the damping of the structure and the seismic threat at the site.

Finally, the expected damage in a building, for a given value of seismic intensity, γ_i, the expected value of β can be calculated using the following expression (Miranda, 1999, Ordaz, 2000).

$$E(\beta|\gamma_i) = 1 - exp\left[ln0.5\left(\frac{\gamma_i}{\gamma_0}\right)^8\right] \quad (9)$$

Standard deviation of the damage

In addition to the estimate of the expected value of the damage as a function of the input intensity parameter, the standard deviation of this function must be considered. For purposes of this estimation, the use of the function presented in Figure 7 is proposed, which relates the standard deviation of the damage with the same measure of intensity raised previously.

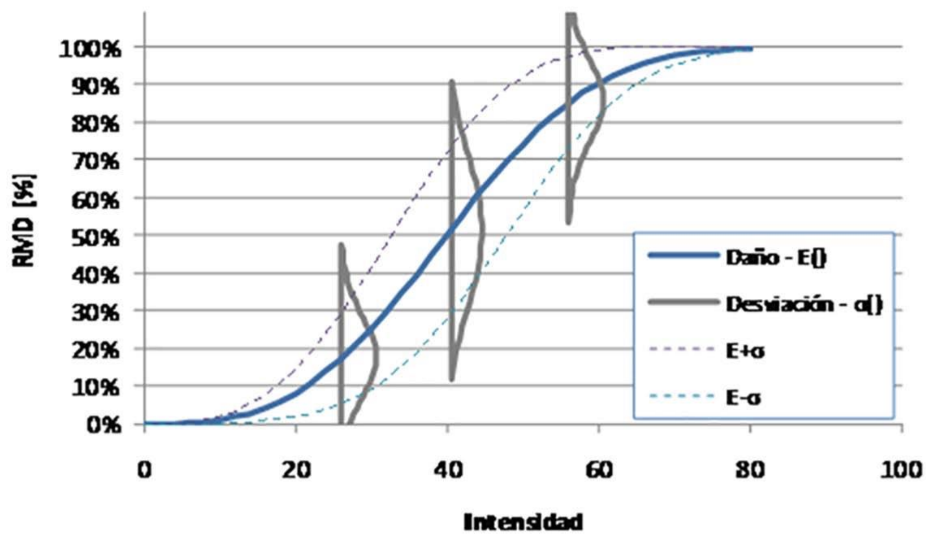


Figure 7. Consideration of a Beta distribution

In addition, it is considered that the probability density of the damage is of Beta type and is given by the following equation:

$$p_{\beta|\gamma_i}(\beta) = \frac{\Gamma(a+b)}{\Gamma(a)\,\Gamma(b)}\,\beta^{a-1}(1-\beta)^{b-1} \quad (10)$$

where: *a* and *b* are parameters that can be calculated from the mean and the coefficient of variation of the damage, *C(β)*, as follows

$$a = \frac{1-E(\beta|\gamma_i) - E\,(\beta|y_i)C^2(\beta)}{C^2(\beta)} \quad (11)$$

$$b = a\left[\frac{1-E(\beta|\gamma_i)}{E(\beta|\gamma_i)}\right] \quad (12)$$

$C^2\,(\beta)$ is calculated as

$$C^2(\beta) = \frac{\sigma_\beta^2(\beta|\gamma_i)}{E\,(\beta|\gamma_i)} \quad (13)$$

Where $\sigma_\beta^2(\beta|\gamma_i)$ is the variance of the loss.

To determine the variation of the variance of the loss, we used the expression of the assigned probability distribution in the classic study of the ATC-13 report (ATC-13, 1985) whose variance has the following functional form:

$$\sigma_\beta^2(\beta|\gamma_i) = Q\ [E(\beta|\gamma_i)]^{r-1}\ [1 - E\ (\beta|\gamma_i)]^{s-1} \quad (14)$$

$$Q = \frac{V_{max}}{D_0^{r-1}\ (1-D_0)^{s-1}} \quad (15)$$

$$s = \frac{r-1}{D_0} - r + 2 \quad (16)$$

V_{max}, D_0 and r are parameters that depend on the structural type, V_{max} is the maximum variance, D_0 is the level of damage for which this maximum variance occurs, and r is considered equal to three.
Once the expected value and the variance of the loss are determined, the probability distribution of the expected damage given a value of seismic intensity is completely defined. Figure 8 shows a curve obtained with a vulnerability function and the associated standard deviation for each of the given threat intensities.

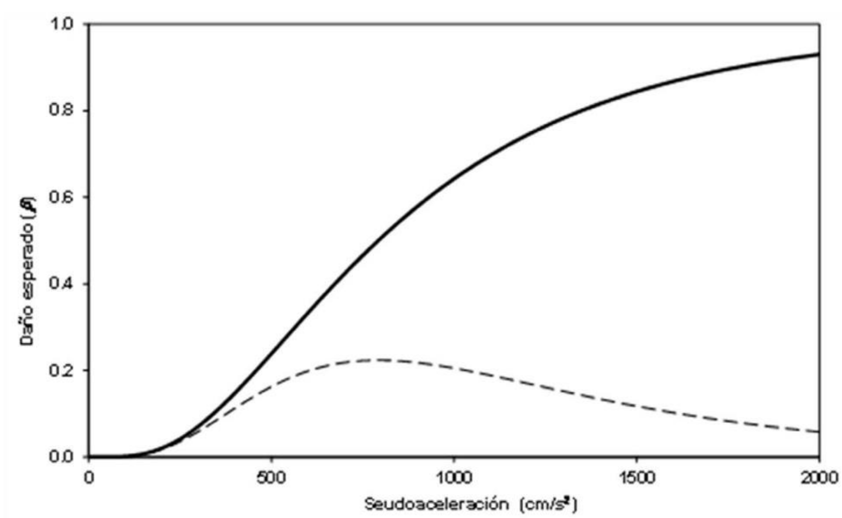


Figure 8. Seismic vulnerability curve and its associated standard deviation.

As the basis for the estimation of structural vulnerability to seismic actions has been presented, the Institute of Engineering has developed different methodologies for the estimation of structural and human vulnerability to the action of other natural phenomena such as wind, flood, sliding hillsides , sand liquefaction, tsunami and storm surge, among others.

Risk estimation

Based on the probabilistic hazard models proposed and, on the inventory, and the value of exposed assets with their corresponding vulnerability functions, a probabilistic hazard analysis model or probabilistic loss modeling has been developed for the country or area of analysis.

To do this, it is necessary to consider the specific methodology for calculating the frequencies of occurrence of specific levels of losses associated with the assets exposed in determined periods and before the occurrence of natural hazards.

The risk by natural hazards is commonly described by the so-called loss curve that specifies the frequencies, usually annual, at which events occur exceeding a specific value of losses. This annual exceedance frequency is also known as the exceedance rate, and can be calculated by the following equation, which is one of the multiple forms adopted by the total probability theorem:

$$v(p) = \sum_{i=1}^{Events} Pr(P > p|Event\ i)\ F_A\ (Event\ i) \tag{17}$$

In the previous equation *v (p)* is the exceedance rate of the loss *p* and F_A *(Event i)* is the annual frequency of occurrence of the event *i,* while *Pr (P> p | Event i)* is the probability that the loss is higher than *p*, given that the *i-th* event occurred. The sum in the above equation is made for all potentially harmful events. The inverse of *v (p)* is the return period of the loss *p*, identified as *Tr.*

The probabilistic hazard analysis is normally performed for a complete set of scenarios specified in the different threats. However, if desired, the analysis can be performed for a single scenario (only one of the addends in equation 17). If the annual frequency of occurrence of this scenario is made to be 1, the application of equation 17 would lead to the exceedance probabilities (no longer annual exceedance frequencies) of loss values p, given that the scenario in question occurred.

- Expected Annual Loss: the PAE (in Spanish) is calculated as the sum of the product between the expected losses for a given event, and the probability of occurrence of said event in a period of one year, for all the stochastic events considered. In probabilistic terms, the PAE is the mathematical expectation of the annual loss.
- Pure Risk Premium: the PPR (in Spanish) corresponds to the value of the PAE divided by the replacement value of the asset. Indicates the cost that must be paid annually to cover the expected losses in a future event. It is expressed in percentage or thousandths of the replacement value.
- Loss Exceeding Curve: the CEP (in Spanish) represents the average annual frequency with which a certain economic loss will be exceeded. It is the most important measure in hazard management, given that it provides basic information for the planning and allocation of resources necessary to meet the particular management objectives. CEP can be calculated from the largest probable event in a year, or evenly for all possible events, depending on their return period. The second approach is generally preferred, since it allows one to consider more than one catastrophic event per year.

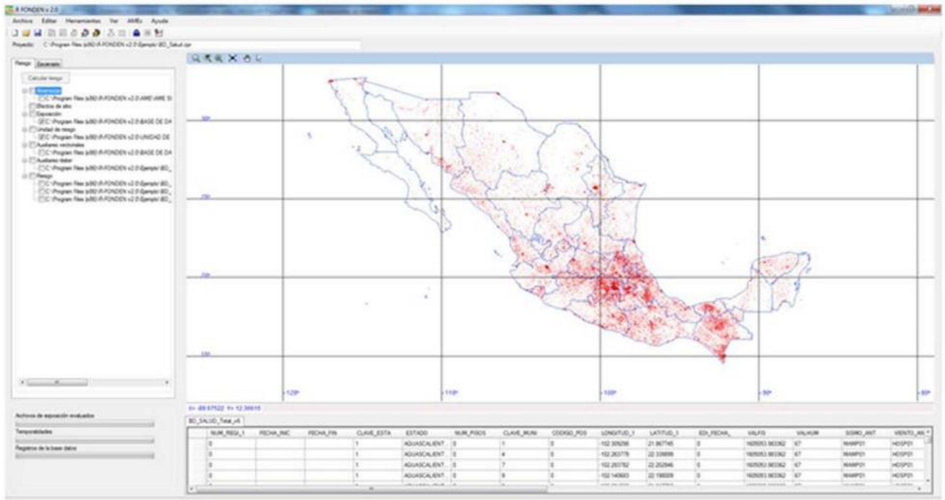
- **Probable Maximum Loss:** The PML represents the global loss value in the portfolio for a given exceedance rate. Depending on the ability of the entity to manage the hazard, it is possible to choose to manage losses until a certain return period.

Implementation of modeling

A) R-FONDEN,

Since 2007, the Technical Committee of the Natural Disasters Fund (FONDEN, for its initials in Spanish) has carried out several studies to estimate, in a better way, the hazard of natural disasters in Mexico. The project "Integration, analysis and measurement of hazard of earthquake, flood and tropical cyclone in Mexico to establish efficient financial mechanisms to protect the patrimony of the trust FONDEN of the National Bank of Works and Public Services (BANOBRAS)", developed by UNAM's Institute of Engineering, is focused on identifying assets exposed to natural disasters such as roads, bridges, hospitals, schools, hydraulic infrastructure and homes in patrimonial poverty, uses the different models mentioned above and combines them in a computational tool called R-FONDEN (Figure 9).

Cover



Main screen
Figure 9. System for the quantification of losses R-FONDEN.

The R-Fonden system has been used to improve the individual insurance policies of the different federal agencies, for example, it allowed designing an insurance scheme for the Ministry of Communications and Transportation in charge of federal highways and bridges, a situation that was previously impossible due to lack of information. In addition, this program was used to design the insurance scheme for the Ministry of Public Education (World Bank, 2012).

B. CAPRA

Since 2009, the World Bank has implemented an initiative in Central and South America, which consists of creating specialized hazard management groups made up of academics from different universities, public servants of different governments and experts in practice. The objective of this initiative is to develop risk assessment and communication tools in order to sensitize decision-makers about the potential of disasters of natural origin, formulate risk management strategies at the national, state and regional levels, in order to develop a common methodology to assess and quantify disaster risk.

For this purpose, a platform for probabilistic risk modeling has been developed, composed of different elements that allow estimating different threats such as: earthquake, rain, flood, landslide, and for the definition of vulnerability. All the above is combined in a tool called CAPRA-SIG.

Figure 10 shows the main screen of the CAPRA-SIG program (World Bank, 2009) where a map of the Mexican Republic shows the location of the different medical units run by the Ministry of Health and the threat of wind caused by Hurricane Stan, which affected the country in 2005.

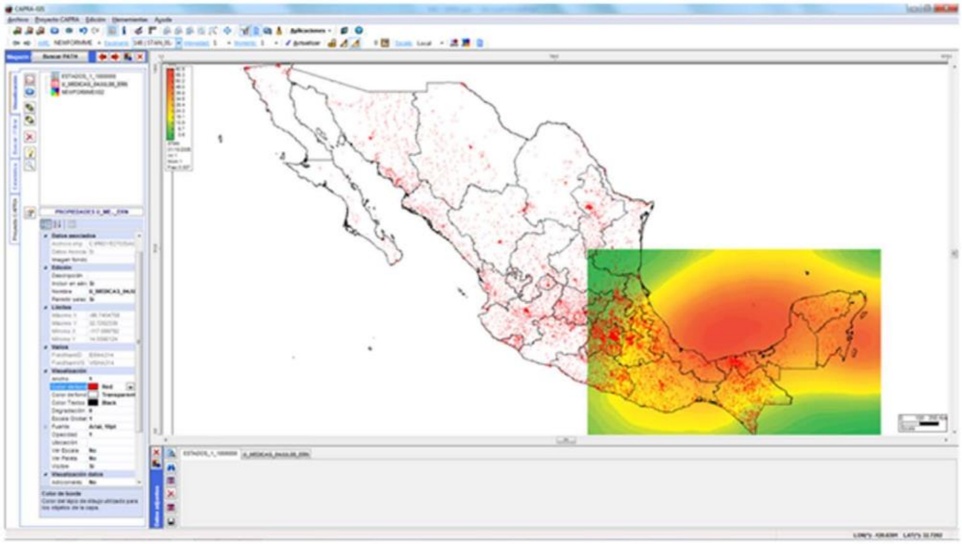


Figure 10. Main screen of the CAPRA-SIG program.

Conclusions

Based on the aforementioned probabilistic threat models and the inventory and value of exposed assets with their corresponding vulnerability functions, it is possible to carry out probabilistic risk analysis or probabilistic loss modeling for a country or area of analysis.

The knowledge of the regional conditions of occurrence of hazardous events, as well as the characteristics reported on important historical events, provide a first idea of the destructive potential of the phenomena that threaten the region, and allow to know in advance, approximately, the periods of return of the most important events.

Current advances in the development and presentation of geographic and geo-referenced information allow important advances in threat analysis of recurring events. The spatial distribution of intensities associated with adverse natural phenomena is a fundamental input for the subsequent risk assessment. The management of this type of information through layers in geographic information systems, allows the automation of risk calculation processes, as well as a simple and agile communication of results.

The estimation of structural vulnerability to various natural phenomena through quantitative methods makes it possible to express risk through different specific indicators needed for a comprehensive risk management.

With this type of tools and initiatives, nowadays it is possible to generate information to carry out an integral risk management, from its transfer to its prevention and mitigation through plans and initiatives that help in the decision making, achieving in this way, a better quality of life for society.

Acknowledgments

The results and methodologies presented in this work have been the product of several years of research carried out by the authors at the Institute of Engineering of the UNAM and in ERN, Evaluation of Natural and Anthropogenic Risks with the collaboration of Miguel A. Jaimes, Carlos Avelar, Marco A. Torres and Octavio Hinojosa.

References

Applied Technology Council (1996). ATC-40, Seismic evaluation and retrofit of concrete buildings. Applied Technology Council, Redwood City California, USA.

World Bank (2012a). FONDEN, Mexico's Natural Disaster Fund - A Review. Joint publication of the World Bank and the Government of Mexico for the meeting of the G20 group in Los Cabos, Mexico.

_____ World (2012b). http://www.ecapra.org (website accessed on 09/20/2012).

Bertero V., Anderson J.C., Krawinkler H. and Miranda E. (2001). Design guidelines for ductility and drift limits: Review of the state-of-the-practice and state-of-the-art in ductility and drift-based earthquake-resistance design of buildings. Report UCB / EERC-91/15, Earthquake Engineering research Center, University of California, Berkeley.

Building Seismic Safety Council (BSSC) (1997) .NEHRP Guidelines for the Seismic Rehabilitation of Buildings, FEMA-273. Federal Emergency Management Agency, Washington, D.C.

CFE, Federal Electricity Commission (1993). Manual of Design of Civil Works: Design by Wind. Federal Commission of Electricity, Institute of Electrical Investigations, Mexico.

Freeman, S.A., Nicoletti, J.P. and Tyrell, J.V. (1975). Evaluations of Existing Buildings for Seismic Risk - A Case Study of the Puget Sound Naval Shipyard, Bremerton, Washington. Memories of the US National Congress of Earthquake Engineering, Berkeley, U.S.A., pp. 113-122

Méndez M. (2010). Spatial-temporal variability of the meteorological drought in Mexico: Dynamic aspects. Doctoral Thesis, Postgraduate in Earth Sciences, UNAM.

Mesinger F., DiMego G., Kalnay E., Mitchell K., Shafran PC, Ebisuzaky W., Jovic D., Woollen J., Rogers E., Berbery EH, Ek MB, Fan Y., Grumbine R., Higgins W., Li H., Lin Y., Manikin G., Parrish D. and Shi W. (2005). North American Regional Reanalysis, Bull. Amer. Meteor Soc., 87: 3, pp. 343-360.

Miranda, E. (1997). Estimation of Maximum Interstory Drift Demands in Displacement-Based Design. Seismic design Methodologies for the Next Generation of Codes, H. Krawinkler and P. Fajfar editor, Balkema.

_____, E. (1999). Approximate Seismic Lateral Deformation Demands in Multistory Buildings. Journal of Structural Engineering, ASCE, Vol. 125, No. 4, pp. 417-425.

Ordaz, M., Arboleda, J. and Singh, S.K. (1995) .A scheme of random summation of an empirical Green's function to estimate ground motions from the future large earthquakes. Bull. Seism. Soc. Am. 95

_____, M. (2000). Methodology for the Evaluation of Seismic Risk Focused on Earthquake Insurance Management. National Autonomous University of Mexico, Mexico City.

Priestley, M.J.N. (1997). Displacement-Based Seismic Assessment of Reinforced Concrete Buildings. Journal of Earthquake Engineering, Vol. 1 No. 1, pp. 157-192.

Rosenblueth, E., Ordaz M., Ssnchez Sesma, F.J. and Singh S.K. (1989). Design Spectra for Mexico's Federal District. Earthquake Spectra, 5, 273 291.

Sözen, M.A. (1997). Drift-Driven Design for Earthquake Resistance of Reinforced Concrete. Memories of EERC-CUREe, Symposium in Honor of Vitelmo V. Bertero, Berkeley, California.

Silva, R, Govaere, G, Salles, P, Bautista, G, and Díaz, G. (2002). Oceanographic vulnerability to hurricanes on the Mexican coast. International Conference on Coastal Engineering, ASCE, Cardiff, Wales.

Vázquez J.L. (2000). Objective characterization of the north of the Gulf of Mexico and its interannual variability. Thesis of Degree in Atmospheric Sciences. Faculty of Electronic Instrumentation, University of Veracruz, Xalapa, Ver.

CHAPTER 2

MICROZONING OF URBAN AREAS, BASIC ELEMENT FOR TERRITORIAL ORDERING, RISK MANAGEMENT AND SUSTAINABLE DEVELOPMENT

Gilbert Francisco Torres Morales
Raymundo Dávalos Sotelo
Saúl Castillo Aguilar
Ignacio Mora González
Miguel Leonardo Suárez

Abstract

This paper presents the results from the naturals hazards for different suburbs and highlights the importance of integrating these results in urban planning. The cities that have been covered for the definition of hazard in the state of Veracruz are: Orizaba, Veracruz and Xalapa, as part of the production of an Atlas of Geological and Hydrometeorological Hazards for the state of Veracruz, financed by the Funds for the Prevention of Natural Disasters FOPREDEN and CONACYT. We integrated the background data of each metropolitan area using a geographic information system (GIS), obtaining different thematic maps, and maps of dynamic characteristics of soils in each metropolitan area.

With all the collected and generated data, a SIG was prepared that allowed us to generate models which define the areas most threatened by earthquakes, floods and landslides. These results were compared with maps of the main features in the urban zones and we established a qualitative classification of areas of high to low risk. It will have the basic elements of information for urban planning and land use. This information will be made available to the authorities and the general public through an Internet portal where people can download and view maps using free software available online.

Introduction

The effects of natural phenomena in Mexico, have caused on numerous occasions major disasters, which are accompanied by economic and human losses, often related to the collapse of structures due to the lack of accurate information and its application, sometimes erroneous, criteria for the design of engineering works. The concern to know better the natural phenomena to take preventive measures through construction regulations, contingency plans and a correct urban planning taking into account natural phenomena, has convinced our societies that the observation, registration and study of natural phenomena lead us to be better prepared.

Particularly in the case of earthquakes, the State of Veracruz has suffered significant damage throughout its history due to earthquakes of large magnitude. It should be recalled that the State ranks second and third in number of fatalities nationwide, only after the earthquake of

September 19, 1985 in Mexico City, which claimed approximately 6,000 victims, according to official records. The Xalapa earthquake of January 3, 1920 (Ms = 6.2) ranks second in the nation in number of victims with 650; of these, 419 were killed by mudslides in ravines, the foregoing highlights the importance of the phenomenon of landslides in mountainside areas, as well as the extreme hydrometeorological hazards conjugated with other natural phenomena. The 1920 earthquake originated in the Sierra Madre Oriental, between the states of Puebla and Veracruz, had an epicenter approximately 35 km southwest of the City of Xalapa (Suarez, 1991, Flores and Camacho, 1922). The third place, according to the number of deaths, corresponds to the Orizaba earthquake of August 28, 1973 (Mw = 7.0) with 539 deaths. This earthquake was located in the state of Puebla very close to the border area between Puebla and Veracruz, at a distance of less than 40 km southwest of Orizaba.

Other earthquakes of great importance that damaged cities of the State, were: The earthquake of January 14, 1931 of Huajuapan de Leon, Oax., (Ms = 7.8), that caused damages in the city of Veracruz; the earthquake of July 25, 1937 of Nopaltepec, Ver., (Ms = 7.3), which affected the cities of Veracruz, Xalapa, Orizaba and Córdoba; the Jaltipan earthquake of August 26, 1959 (Ms = 6.4), which totally destroyed the city and affected the cities of Acayucan, Minatitlan and Coatzacoalcos; the earthquake of March 11, 1967 (Mw = 5.7), known as the tremor of Veracruz for the damage caused in approximately 50 buildings.

The increase in population, the industrial activity and the high probability of affectation by natural phenomena, show the importance of defining the hazards in the urban areas, in order to be able to take preventive measures to disasters and be able to carry through urban planning according to the natural environment. Frequently, the lack of economic resources accompanied by the lack of more precise information about the area, has as a consequence that many houses and even large structures are built without adequate technical advice (Torres, 2000).

Methodology

Microzoning

In general, microzoning investigations consider all-natural phenomena that can potentially affect an area of interest, such as: earthquakes, floods, landslides, soil liquefaction, avalanches, erosion, tsunamis, etc., and prepare the map of threats for each of the potential hazards. These maps are superimposed and then the area considered is divided into sectors according to the degree of severity of a hazard. Geographic information systems (GIS) are very useful for these tasks.

The seismic hazard is a phenomenon that considerably affects urban areas when it occurs if preventive measures are not taken and generally their consequences impose a large economic bill and loss of human lives. Studies on the distribution of calamities caused by earthquakes indicate that areas of intense damage can be very localized, and that the magnitude of these damages can change abruptly at very short distances, that is, seismic intensities can vary considerably between two nearby points. (Fig. 1). This led to the hypothesis that the essential factor for the evaluation of the damage of the structures are the local subsoil conditions (or site effects) (Trigos, 1988). The importance of site response has been recognized since the beginning of Seismology, especially in Japan, and has been documented since the beginning of the 18th century (Giraldo et al., 1999).

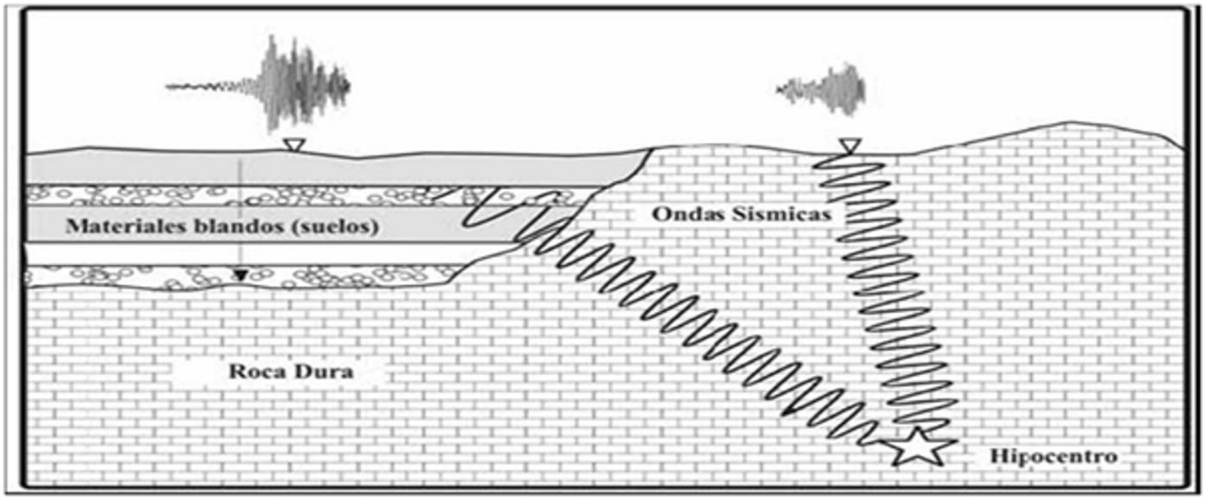


Figure 1. Phenomenon of amplification of seismic waves in soft soils.

Seismic microzoning studies are a branch of microzoning studies and are the most important for zones or cities exposed to earthquakes; these are interdisciplinary studies of Earth Sciences that, duly synthesized and drawn, allow to prepare the map of seismic hazards. These studies cover a few kilometers, including the existing urban area and its possible expansion, and consider the effects that an earthquake would have taking into account the mentioned significant site effects mentioned, shown by isoperiod curves and zones of relative amplification to firm terrain. , to delimit seismic microzones; This is an easy document to interpret and apply in land use plans for the reduction of natural disasters, as well as for building regulations.

The methodology used to determine the effects of site in the Conurbation Zones (CZ), was the experimental, same that has been occupied in many studies of determination of site effects of cities in Mexico (Torres, 2008), as in the Federal District (Mexico City) , Oaxaca, Puebla, Morelia, Tehuacan, Guadalajara, and that is divided, in general, into four phases: The first phase consists of defining the seismogenic zones through the study of the global seismicity where the city is located, as well as, an investigation of the historical earthquakes that have affected the area and the city. The second phase consists of investigating and defining the characteristics of geology, morphology, geotechnics, hydrology, historical hydrology, as well as earthquake damage. The third phase is seismic monitoring, using different types of records to quantify the behavior and characteristics of the subsoil. The records of strong seismic movements, weak and microquakes (environmental vibration), were analyzed, in addition to applying all the particular techniques for each of these records.

The fourth phase consists of defining, from the maps and information integrated in the GIS, the map of isofrequency curves, isoperiods, the relative amplification to firm terrain and the classification map of the seismic microzones, which indicate the zones with local amplifications due to the type of soil. With the above, suitable points for the construction of permanent seismic monitoring stations can be selected, as well as establishing some recommendations for the use of these maps and include them in the construction regulations.

Determination of the site effect

The amplification of seismic waves in soft sediments near the surface has been recognized since the beginning of seismology; this amplification of seismic waves during an earthquake can trigger damage to the structures that are cemented on these soils. One way of inferring these unfavorable soil characteristics is through the Nakamura technique, which consists of recording the environmental vibration at a point in an urban area and obtaining the spectral ratios between the horizontal components plus the vertical of the same record originally proposed by Nakamura (1989).

To evaluate the amplification of the seismic waves of the soils in the different conurbation zones, environmental vibration was recorded in the conurbation of Orizaba, 121 points were taken, in Veracruz 238 and in Xalapa, 517. Two triaxial accelerometers were used, one of the Refteck brand, model 130-anss / 02 and another the CMG-5TD of the Guralp System brand, in addition to that in some sites environmental vibration was also registered with a CMG-6TD broadband seismograph of the Guralp System brand. After orienting and leveling the devices at each point, an average of ten continuous minutes of environmental vibration was recorded, these were recorded in the internal memories of the equipment that were then downloaded to a computer for analysis. From the records of environmental vibration obtained, we proceeded to its spectral analysis to obtain its H / V ratios.

The first part of the analysis consists of the visualization of the seismic traces to select those segments of the registry that are not contaminated by transients of short duration that may affect the stability of the signals (mainly vehicles and pedestrians in the vicinity of the instrument). From the records, two-minute segments are selected for analysis and from each of these, windows of between 20 and 30 seconds in length are chosen, which were used to calculate Fourier spectra. By choosing several log windows for each point, one can obtain more robust estimates of the Fourier amplitude spectrum for each observation point. Finally, the Nakamura technique is applied for each of the points, and an estimate of the dominant frequency of the site is obtained. The analyzes were carried out with the help of the Degtra (Ordaz, 1990) and Geopsy (Geopsy, 2007) programs.

As an example, Figure 2 shows the average spectral ratios and their respective standard deviation for three points of environmental vibration in the city of Xalapa with different soil characteristics. The solid line indicates the average of the spectral quotients for different information windows, while the broken line indicates the average plus-minus one standard deviation. A good concordance between both horizontal components is observed.

In addition, seismic monitoring stations were installed on firm terrain (reference station) and on soft terrain, in accordance with the geological-geotechnical characteristics (Table 1), using Guralp brand broadband seismometers, model CMG-6TD. Up to eight seismic monitoring stations have been operated simultaneously, recording more than 100 earthquakes to date, allowing the standard technique to be applied and corroborating the results obtained using the Nakamura technique.

The seismic monitoring network in the Xalapa Conurbation Zone (XCZ) has served to record the seismic sources of the seismogenic sources that affect the area and even earthquakes from all the seismogenic sources of the Mexican Republic, being the earthquakes perceptible by the population those that generate the speeds and larger accelerations in the stations. Previously there was only one broadband seismograph in each station, but because in recent earthquakes, seismographs in soft terrain have become saturated, accelerators are being arranged together with seismographs so as not to lose information during earthquakes.

The most hazardous are the most active and are at a shorter distance and are associated with historical earthquakes that have caused damage in the XCZ, these earthquakes could be grouped into four: Subduction earthquakes, subduction depths, cortical of the neo-volcanic axis and the locals and the gulf. The return period also goes in that order and earthquakes of all these zones are registered by the network. The most important earthquakes that have been recorded by the network since 2007 are approximately 15, and of the representative earthquakes that have been perceived by the population and cause alarm are: The Oaxaca earthquake of February 12, 2008 (M = 6.6); the earthquake in Puebla on May 22, 2009 (M = 5.7); September 8, 2009 (M = 5.1), located in Isla, Ver .; the earthquake of April 7, 2011 (M = 6.7), 83 km from the Choapas Ver; the earthquake of February 25, 2011 (M = 6.0), which was located southwest of Sayula, Ver.;

Table 1: Location of the XCZ seismic monitoring network

Station		Address	Type of Terrain	Altitude	UTM Coordinates	
Name	Key				X	Y
Cerro	XCE	119 Herrera Tejeda, Federal	Firm	1513	718,712.000	2,162,703.000
CCTUV	XCC	20 Francisco J. Moreno, Zapata	Bland	1374	717,775.000	2,159,292.000
CCT01	X01	#1 2º Privada de Jazmin, B. Juarez	Bland	1273	716,420.000	2,160,264.000
Lagos	XLA	#67 13 de Septiembre, Isleta	Bland	1345	718,254.000	2,159,026.000
Electricistas	XEL	48 Jose F. Diaz, Electricistas	Bland	1386	718,864.000	2,159,572.000
Hayas	XHA	#7 Priv. Eucalipto, Benito Juarez	Bland	1392	716,069.000	2,159,735.000
Clavijero	XCL	158 Clavijero , Centro	Bland	1446	717,802.000	2,161,401.000
Idiomas	XID	Galeana and 7 de Noviembre	Bland	1385	717,006.000	2,160,316.000

The most important seismogenic sources that generate the greatest hazard are the most active and are located at a less distance, which are associated with historical earthquakes that have caused damage in the XCZ, these earthquakes could be grouped into four: subduction earthquakes , the subduction depths, the corticals of the neo-volcanic axis, the local ones and the gulf. The return period also goes in this order and the earthquakes of all these zones are registered by the network. The most important earthquakes that have been recorded by the network since 2007 are approximately 15. The representative ones that have been perceived by the population and cause alarm are: The Oaxaca earthquake of February 12, 2008 (M = 6.6), the earthquake of Puebla from May 22, 2009 (M = 5.7), the earthquake of September 8, 2009 (M = 5.1), located on Isla Ver., The earthquake of April 7, 2011 (M = 6.7) to 83 km from las Choapas Ver., the earthquake of February 25, 2011 (M = 6.0), which was located southeast of Sayula, Ver., the earthquake of September 28, 2011 (M = 4.1), located at 32 km in the southeast of Misantla; February 14, 2012 (M = 4.1), located 10 km from Sayula, Ver.; on March 20, 2012 (M = 7.4), 29 km south of Ometepec, Gro., the strongest sense to date and that has generated the greatest velocities and accelerations a = 9 gales and V = 0.31 m / s. Some of the most important earthquakes recorded in the stations are presented in Table 2.

Table 1. Main earthquakes recorded by the XCZ network of stations.

ID	Local Date	Local Time	M	Seismic Monitoring Stations													
				XCE	XCC	XSU	X01	XEL	XLA	XCL	XHA	XID	XBU	XSB	XPS	XII	XFC
9	07/05/2007	20:09:19	6.2	X	X												
19	10/20/2007	10:14:46	4.5	X		X											
21	02/12/2008	06:50:18	6.6	X			X										
32	04/14/2008	22:03:06	6.5	X				X	X	X	X						
41	07/03/2008	13:21:20	4.7	X	X							X	X				
52	09/23/2008	21:33:06	6.4	X										X			
72	05/22/2009	14:24:18	5.7	X								X				X	
81	09/08/2009	00:14:31	5.1	X								X			X	X	
136	03/20/2019	12:02:00	7.4	X	X							X					X

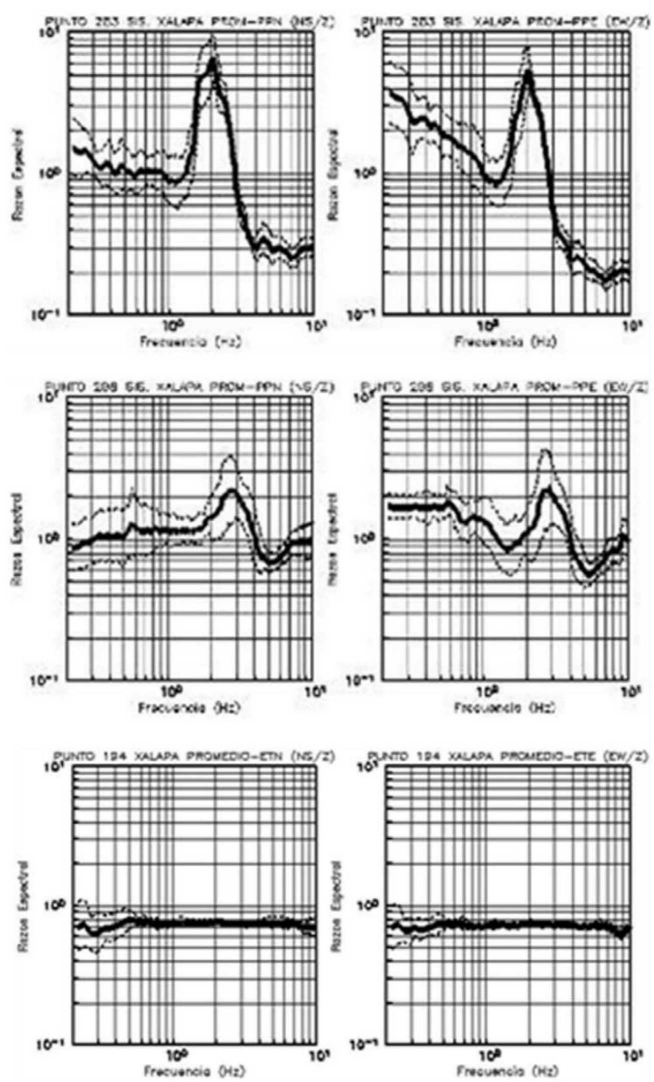


Figure 2. Typical spectral arrays for a record of vibration in firm, intermediate and soft ground (From top to bottom respectively.)

Seismic microzoning maps

The seismic microzoning studies gather the most important information of the conurbation area under study, such as geology, geotechnical, hydrological and historical hydrology maps, as well as generating new information such as conducting an investigation of the most important earthquakes that have affected the metropolitan area. and a mapping of the damage. For the conurbation zones of Orizaba, Veracruz and Xalapa, this compilation of information was carried out. In addition, from the field studies, to obtain the dynamic characteristics of the soils, consisting of the recording of environmental vibration and the recording of earthquakes with non-permanent stations in firm and soft ground, to apply the techniques of Nakamura or H / V and that of standard spectral ratios.

Summary of Results

The results of the spectral analysis of environmental vibration and of the earthquakes recorded in the seismic monitoring stations were integrated by means of a geographic information system (GIS), generating thematic maps in all the conurbation zones such as: vibration points, geological, isofrequencies , isoperiods, and isoamplifications for all the conurbation zones (Torres et al., 2011), as an example, the results for the Xalapa metropolitan area (Torres et al., 2009) are presented (Fig. 3.); These are important products since the results obtained from the environmental vibration and earthquakes can be combined with those of the main characteristics of the conurbation zones. The maps elaborated in this research were processed with the help of the ArcGis program (SIG) of the ESRI company. All these maps contain detailed information and are mounted in the GIS on the INEGI cartography, so this information is georeferenced and is susceptible to update, which makes the study dynamic. In addition, queries can be made in detail for any point, of the aforementioned characteristics, which will be of great help for construction professionals, civil protection, appraisers, insurers, etc.

This allowed an analysis of the seismic hazards in the conurbation zones and to classify zones from the fundamental period of the soil, obtaining as an example for the Conurbation Zone of Xalapa (Fig. 3.): Zone 1 (Low Hazard): This The zone is the most stable, since it is settled under basaltic spills of recent origin and on compact material of medium to high stability product of the last volcanic emissions. This area is located in the central part of the urban area of Xalapa, on the lava spills emitted by the Cerro de Macuiltépetl. This zone has values of periods less than 0.3 and amplitudes less than 2. Zone 2 (Intermediate Hazard): This zone is of medium stability, since it is mostly on compact sandy-clay silts, pyroclastic flows and volcanic breccias, this zone presents values of periods between 0.3 to 0.6 and amplitudes of 2 to 4. Zone 3 (High Hazard): This area is of low stability, since it is mostly on high and medium plasticity silts, on silty sands product of the spills of basaltic lava very altered of Cerro Colorado and on deposits of alluvial material transported and deposited by water currents. In places they constitute hills with steep slopes, making their slopes unstable. In this zone values of periods greater than 0.6 and amplitudes greater than 4 are presented.

It can be observed from the integrated results through the GIS, that the areas with less favorable soil characteristics have the most unfavorable site effects, ie periods and high amplifications. The periods found in the XCZ have values ranging from 0.07 to 1.14 and the amplifications relative to firm terrain from 1 to 6 times, and although this last parameter is considered approximate using the Nakamura technique, it gives us an idea of the areas that can have a greater response. The periods found are not very large, compared to other cities such as Mexico City, and suggest not very deep strata. Soil periods could be significant for buildings whose vibration periods coincide or are close, since there would be a greater response of these buildings, due to the possible resonance of the structure with the ground.

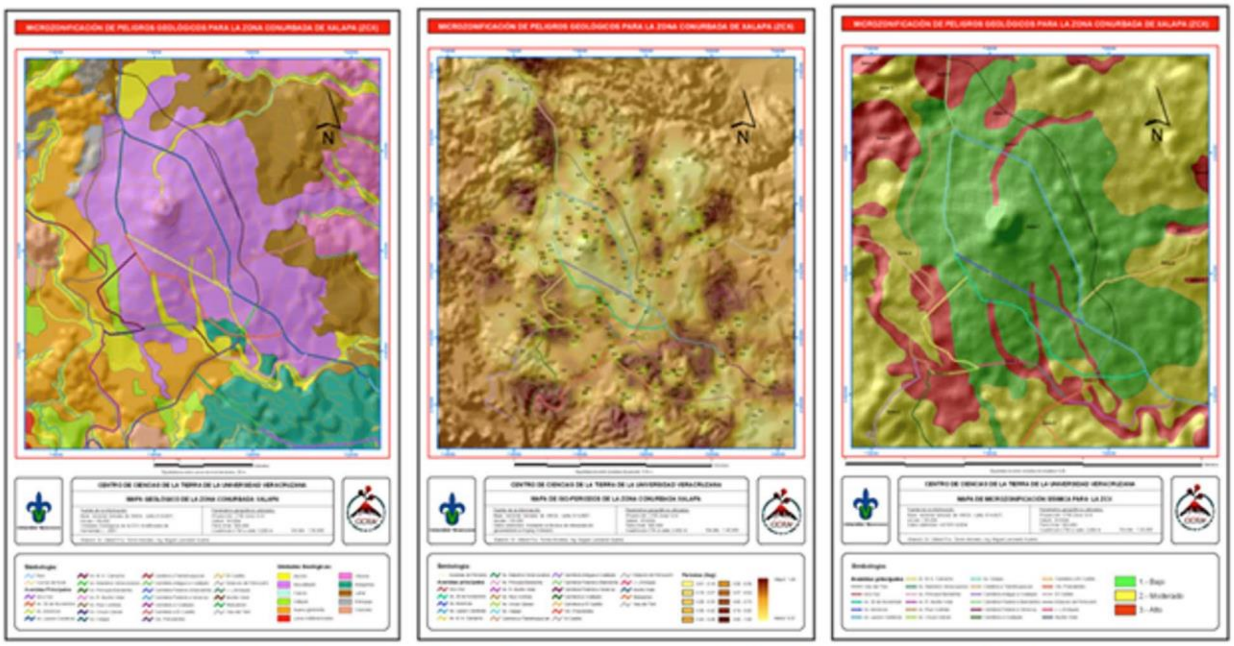


Figura 3. Geología, isoperiodos, y de microzonificación sísmica de la Zona Conurbada Xalapa

Figure 3. Geology, isoperiods and seismic microzoning of Xalapa's Conurbation Zone

Microzoning of flood hazards

To delimit the areas susceptible to flooding, the methodology used to assess flood hazard included the following steps in the investigation: historical background, weather conditions, existence of water courses in the area, topographic conditions (low zones), permeability conditions and land use, human intervention, identification of critical points, calculation of micro-watersheds, identification of critical points of flood overflows, flood hazard dimensioning, affected surface area, flood height, probability of occurrence and finally the development of hazard maps by flood.

In the analysis process, a high-resolution digital elevation model was used, provided from the ASTER Global Digital Elevation Model project freely by NASA (http: // www. Serve.net/) and a Geographic Information System gvSIG-Sextante using the hydrological tool MFD. This modeling tool is based on the "Multiple Flow Direction Algorithms" model, which considers a two-dimensional flow, which calculates the direction and accumulation of surface flows from the differences in slopes and land exposures, resulting in the network of runoff and the limits of nano-micro and hydrographic sub-basins.

To obtain the zoning of flood hazard areas, the humidity index, also known as the composite topographic index, was applied. The index is a function of the slope and the areas that provide flow in the direction of the slope; For this reason, flat areas with a greater flow contribution will have a higher risk of flooding, while the areas located on the slopes will have lower values of hazard of flooding. The index is associated with the shape of the land and the properties of the soil. In addition, the results obtained were verified, superimposing the polygons that the municipal water and sanitation commission (CMAS) of the Xalapa municipality identifies as critical flood sites, thus observing the correspondence between the results obtained in the modeling and the Sites identified as problematic (Fig. 4.).

Microzoning hazard due to landslides on the XCZ

The use of the Geographic Information System (GIS) was a great help in identifying the parameters required for the analysis, the information used for this process was a high-resolution ASTER digital elevation model (MDE). With the MOU, contour lines were drawn up at every 2m of equidistance, the areas of greatest slope were delimited and those of greatest hazard were classified, with the purpose of verifying and evaluating them in the field. In this first stage, the basic parameters recommended by CENAPRED to assess slopes, and the information collected in a seismic microzoning study were considered.

The identification of geotechnical, geological and topographic attributes allowed us to make a qualitative estimate of the threat of a landslide. The factors to be classified are: the type of hillside, location, physical characteristics of the site, topographic, historical, geotechnical, geomorphological, environmental factors, and if it exists, type of runoff and housing. Finally, an estimate of the threat is made by adding the rating for each stage, in order to assess the degree of the threat that could be assigned to the hillside, rating it from very low to very high. With the results obtained and the application of the GIS, the hazard zones were characterized qualitatively before the landslides, distinguishing zones of low, moderate and high hazard, being represented on the map from green to red (Fig. 4.).

The resulting final map that brings together the hazards in the Xalapa area is presented as a general microzoning map (Fig. 4.). The integration of these cartographies and databases through a GIS, is an aspect of great interest since it allows modifications to the extent that changes occur in the physical environment, in economic activity or in the development of populations. In addition, it allows to handle a large amount of information, crossing it to obtain new maps resulting from the analysis of the variables and factors considered to influence the processes. Being a fundamental element so that authorities, legislators and technicians can base their decisions in the fields of their competence, such as the elaboration of laws and regulations or in matters of territorial planning, civil protection and disaster prevention.

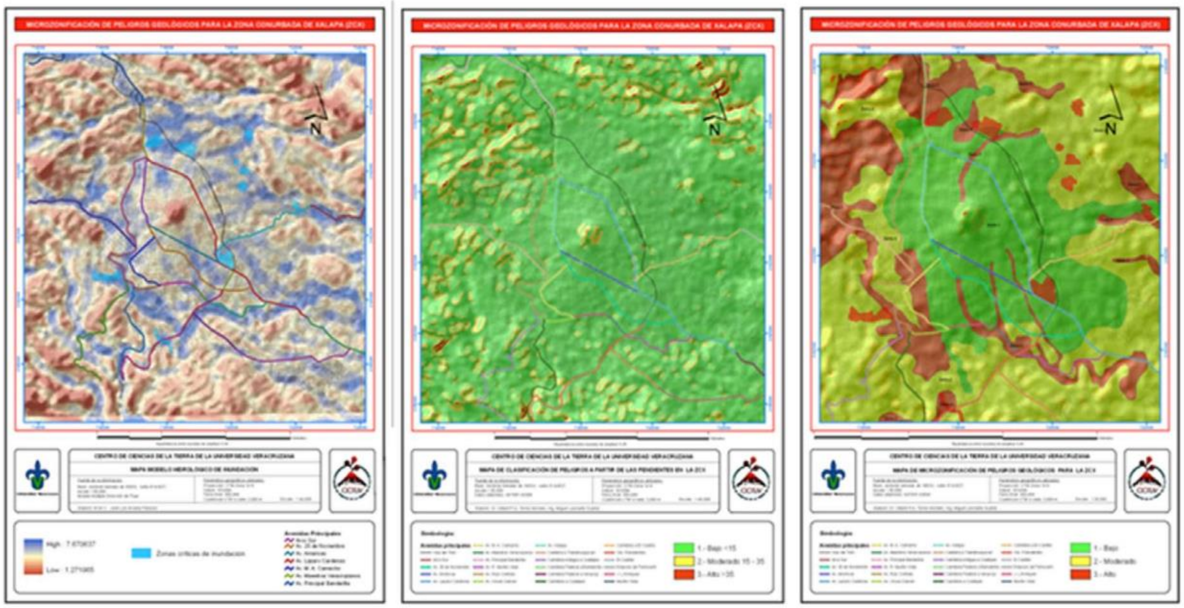


Figura 4. Mapa de modelo hidrológico de inundación, clasificación de pendientes de acuerdo a criterios cualitativos propuestos y mapa general de microzonificación.

Figure 4. Map of hydrological flood model, classification of slopes according to qualitative criteria proposed and general map of microzoning.

Land use planning, risk management and sustainable development

In addition to the determination of local hazards, it is important to consider the main objective of a disaster mitigation program, which is to reduce human and material losses, so that the sustained development of a city, region or country is not interrupted, as a result of a catastrophe that significantly hinders the pace of its social and economic growth. This objective can be achieved if the RISK is reduced (Andrew et al. 1991).

The RISK depends on two factors: the HAZARD or natural THREAT and the VULNERABILITY of the constructions.

HAZARD or THREAT is the degree of exposure of a place to natural phenomena within a given period, regardless of what is built on that location. In general, what man can do to reduce hazard is little and very expensive.

VULNERABILITY is an intrinsic property of the structure or urban area, a characteristic of its own behavior in the face of the action of a natural phenomenon, described through a cause-effect law, where the cause is the natural phenomenon and the effect is the damage (Sandi H. 1986), and refers to the degree of damage that buildings can suffer that man does and depends on the characteristics of its design, the quality of the materials and the construction technique, in general, of Your possible answer.

RISK is, therefore, the result of the exposure of man-made construction, with the degree of vulnerability that is inherent to it, against the hazard to which it will be subjected. This is considered by insurance companies to set the respective premiums and reinsurance companies to decide whether or not to accept reinsurance and at what cost. These definitions accepted by the UN refer to individual buildings from which the respective economic losses can be estimated.

Within the framework of the sustainable development approach that postulates economic growth, social equity, sustainability of natural resources and governance, a series of points are established on the agenda for risk management, but the most important and significant will be that the population and Urban developments follow the philosophy of the disaster mitigation program and this will be achieved to a large extent if the effects of natural phenomena are considered. Governments in general make a series of important efforts so that the planning of urban areas has a good organization and is carried out in accordance with current laws, but sometimes the considerations of the effects of natural phenomena are very superficial. An important point in territorial planning programs should be to promote studies of microzoning of hazards due to natural phenomena.

The results of the seismic microzoning for three urban areas and microzoning of geological hazards for the city of Xalapa were delivered to the users of the projects.

In addition, it has been made available on a website (https://sites.google.com/site/microzonecct/), which is summarized in the form of maps, this information is also presented in a format from which You can consult the information through the Google Earth program, so you can view these results in detail (Fig. 5). What will help the population to identify the places where they plan to build or buy, which would help to make decisions for both the population and the authorities.

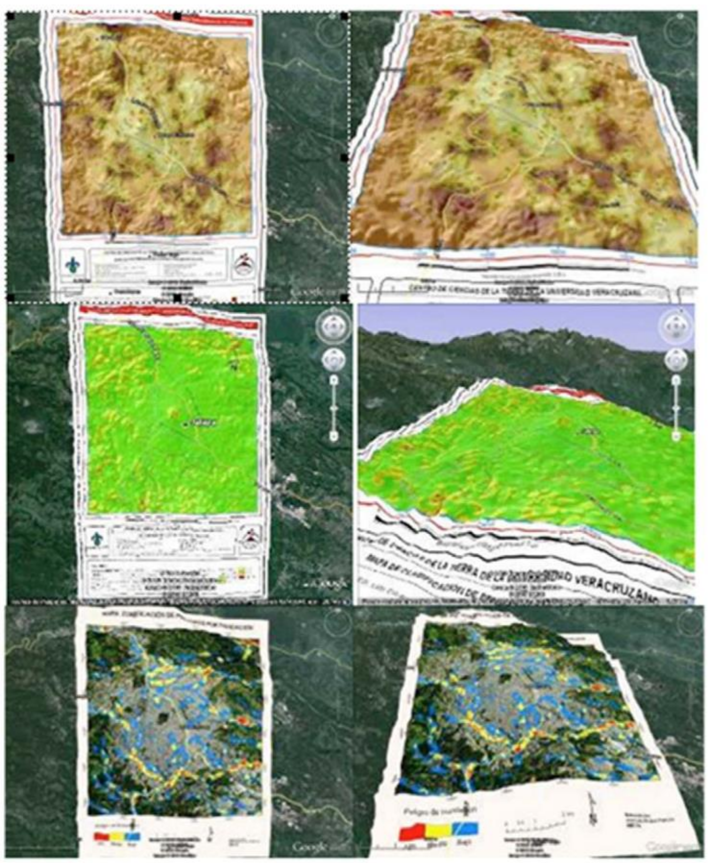


Figure 5. Maps of isoperiods, of hydrological model of flooding and classification of slopes in Google Earth, for their visualization and analysis.

References

Andrew W., RJ Spencer, A. Pomonis, UNDP / UNDRO, (1991), "Vulnerability and risk assessment", United Nations for disaster development and relief (UNDRO), disaster management training program (DMTP), first edition.
Flores T., H. Camacho. (1922). "Mexican Earthquake of January 3, 1920", Bulletin 38, Mexican Geological Institute. http://bcct.unam.mx/bogeolpdf/geo38/.
GEOPSY (2007), Version 2.6.3, (SESARRAY-2.0.5), http://www.geopsy.org.
Giraldo V., A. Alfaro, L.G. Pujades, J.A. White hair. (1999). "Estimation of local effects with seismic movements and microtemblores", Monograph International Center for Numerical Methods in Engineering (CIMNE), Editor A.H. Barbat ISBN: B-42176-99.
Nakamura Y. (1989) "A method for dynamics characteristics estimation of subsurface using microtremor on the ground suface", QR of RTRI, 30, No. 1, 25-33. .
Ordaz M. and C. Montoya. (1990-2002). "DEGTRA Program". Engineering Institute, National Autonomous University of Mexico.
Sandi H., (1986), “Vulnerability and risk analysis for individual structures and systems”, Report of the Working Group of the European Association for Earthquake Engineering, Proceedings of the 8th ECEE, Lisbon, Portugal.
National Seismological Service, (2009), http://www.ssn.unam.mx
Suárez, G. (1991). “The earthquake of Xalapa of January 3, 1920”, Journal of Seismic Engineering, SMIS, # 42, Mexico D.F.
Trigos J. L., (1988), “Seismic risk, constructions and regulations in Mexico”, Memories III National Symposium on Seismic Engineering, Guadalajara. Jal. October 30- November 1 1988.
Torres G., (2000), "Importance of seismic microzoning of the main cities of the state of Veracruz." National Congress for Disaster Prevention, 1st Southeast Regional Forum on disasters towards a culture of prevention, Xalapa, Veracruz. March 2000. Published in the Journal of the Mexican Society of Public Health, A.C.: Hygiene Magazine, Vol. IV, No.2, May-August 2002.
_____, G. (2008), “Seismic microzoning of the Veracruz conurbation zone and evaluation of the structural seismic vulnerability of the historic center”, University of Veracruz, Engineering Institute, Veracruz Zone, Doctoral Thesis, Veracruz. http://www.uv.mx/insting/Tesis/tesis-2008.
_____, G., J. Lermo, R. Dávalos, I. Mora, J. Hernández, M. Leonardo, D. Huesca. (2009). "Seismic microzonation of the conurbation area of the City of Xalapa (ZCX), See", Memories XVII National Congress of Seismic Engineering, Puebla, Mexico.
_____, G., Rodríguez M., J. Lermo, R. Dávalos, I. Mora, J. Hernández, M. Leonardo, (2011). "Seismic microzonation of three cities in the state of Veracruz, Mexico", Memories XVIII, National Congress of Seismic Engineering, Aguascalientes, Mexico.

Chapter 3

Estimation of seismic hazard of Barcelona and its application in determining the seismic risk of the city

Armando Aguilar
Luis G. Pujades
Alex Barbat
Mario G. Ordaz
Nieves Lantada

Abstract

This paper describes the main steps used in the probabilistic estimation of the seismic hazard of Barcelona, and it is mentioned how said seismic hazard was used in the probabilistic estimation of the seismic risk of the city. For comparative purposes, the seismic hazard of Barcelona was estimated both in terms of the excess rates of macroseismic intensities, and in terms of exceeding rates of the maximum ground acceleration (PGA). In calculating the seismic hazard, the computation code CRISIS2008 (Ordaz et al, 2008) was used, which is based on the methodology proposed by Cornell (1968) and Esteva (1970). This code incorporates valuable tools that allow estimates of seismic hazard, with an important level of detail. In addition, CRISIS2008 allows to obtain seismic hazard results both in terms of exceedance rates versus PGA, and in terms of exceedance rates versus macroseismic intensities. According to the results, in Barcelona the value of PGA equal to 85 cm / s2, has an average return period of 475 years. While the results obtained in terms of macroseismic intensities, indicate that the macroseismic intensity that has an average return period of 475 years, corresponds to a value between VI and VII. Seismic hazard curves in terms of exceedance rates versus macroseismic intensities were obtained to be used in the estimation of the seismic risk of the city through the probabilistic method of vulnerability indices (Aguilar, 2011). According to the results, in the city there are buildings with a high level of seismic risk, the latter is due to the fact that although Barcelona is located in an area of seismicity between low to moderate, there is a significant percentage of buildings with significantly high levels of seismic vulnerability. The seismic risk curves obtained are expressed in terms of exceedance frequencies versus degrees of seismic damage.

Introduction

There are currently various methodologies for estimating the seismic risk of buildings on an urban scale. One of them was recently proposed and is known as the probabilistic methodology of vulnerability indices (Aguilar, 2011). This method considers both the seismic hazard and the seismic vulnerability, to estimate the seismic risk of buildings. Particularly, the seismic hazard or the seismic threat is expressed in terms of frequencies of excess of macroseismic intensities. This paper describes the procedure and the main results obtained when estimating the seismic hazard of Barcelona, with the purpose of using such hazard results in the estimation of the seismic risk of residential buildings in Barcelona. For this purpose, two procedures are analyzed: in the first, the excess rate curves of macroseismic intensities are obtained directly, that is, the seismic hazard is estimated from seismic data of the seismic sources in terms of macroseismic intensities and by the use of laws of attenuation of macroseismic intensities. While in the second procedure, the seismic hazard curves in terms of macroseismic intensities, are obtained by transforming seismic hazard results obtained in terms of exceeding rates of the maximum ground acceleration (PGA). The first procedure is the most recommended to estimate the seismic hazard, required in the probabilistic method of vulnerability indices to estimate the seismic risk of buildings. However, the second procedure is considered in the present work for comparison purposes, and because this procedure includes considerations that can be taken into account, in the regions where the available seismic hazard studies are in terms of PGA.

Seismic hazard in Barcelona

The city of Barcelona is located in the northeast of the Iberian Peninsula, which is usually considered a microplate that is part of the Eurasian plate, acting as a patella in the interaction between the Eurasian and African plates (Casas-Sainz and De Vicente, 2009; Rosenbaum et al, 2002; Jabaloy et al, 2002). On the other hand, the closest distance from Barcelona to the edges of the Eurasian plate with the African plate is more than 500 kilometers. Thus the seismicity that has the greatest effect on Barcelona is not that which occurs within the limits of these tectonic plates, but that which is generated inside the Eurasian plate. It is important to highlight that it has been estimated that in the early Cretaceous - Hauterivian (approximately 135 million years ago), the Iberian Peninsula constituted a single tectonic plate (Casas-Sainz and De Vicente, 2009; Jabaloy et al, 2002).

Figure 1 shows the epicenters of earthquakes of intensities greater than or equal to V, which occurred between 1152 and 1998, in the region of Catalonia and surrounding areas. Such earthquakes are relevant because it is considered that from the degree of intensity V, building damage begins to be generated (Grünthal, 1998). This figure shows how the seismic hazard of the city is influenced by the coastal areas of the Mediterranean Sea and, further north of the Pre-Pyrenees and Pyrenees.

By looking at Figure 1, it is possible to identify that important earthquakes have occurred in Barcelona and in the region surrounding that city. Therefore it can be said that Barcelona has been subjected to significant levels of seismic intensity. For example, Table I shows some of the seismic intensities estimated to have been presented in Barcelona.

Due to the social and economic importance of the city of Barcelona, numerous investigations related to the seismic hazard of that city have been developed. Some of them correspond to specific studies of the seismic hazard of Barcelona and Catalonia (Irizarry et al, 2010; Secanell et al, 2004; Irizarry et al 2003b; Goula et al, 1997; Secanell, 1999), and others correspond to different aspects of the seismic hazard of Barcelona and Catalonia (Secanell et al, 2008; Perea and Atakan, 2007; Ojeda et al, 2002; Jimenez et al, 2001; Secanell et al, 1999).

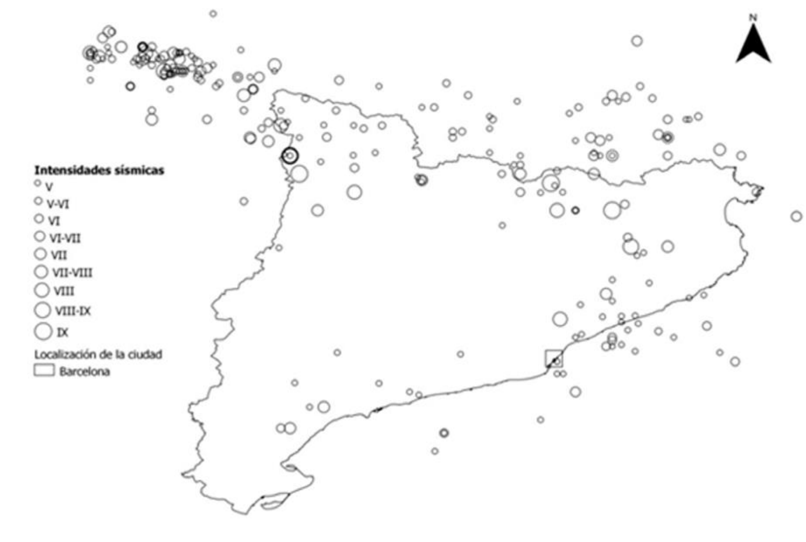


Figure 1 Location of the main epicenters of earthquakes with intensities greater than or equal to V, occurring between 1152 and 1998 in the region of Catalonia and surrounding areas (Susagna and Goula, 1999).

Date	Intensity in the region of the city of Barcelona
March 3rd, 1373	V-VI
February 2nd, 1428	VI-VII
May 25th, 1448	V-VI

Table 1 Degrees of seismic intensity EMS-98 estimated in the city of Barcelona, due to the occurrence of important earthquakes in the fourteenth and fifteenth centuries (Olivera et al, 2006).

In the work carried out by Secanell et al (1999), they proposed a map of seismic areas of Catalonia, in terms of MSK intensities of nests by Medvedev, Sponheuer and Karnik (Musson and Cecic, 2002), associated with a return period of 500 years Specifically, they proposed 5 seismic zones for all of Catalonia, and placed Barcelona in zone 2. This last zone corresponds to a seismic intensity between VI and VII (MSK), for a hard ground, and for a return period of 500 years . This last type of soil is characterized by being a compact, granular material, with a shear wave speed between 400 and 800 m / s, and with good to very good mechanical characteristics (Fleta et al, 1998).

In spite of the various studies of seismic hazard that have been done for Barcelona, in the present work it has been considered convenient to make a new estimate of the seismic hazard of said city, with the purpose of: 1) illustrating the probabilistic approach proposed in the Probabilistic methodology of vulnerability indices, to estimate the seismic hazard, 2) obtain specific results of seismic hazard in fully probabilistic terms, required to estimate the seismic risk through the probabilistic methodology of vulnerability indices and, 3) incorporate into the hazard analyzes Seismic updates made in the CRISIS2008 code (Ordaz et al, 2008).

The main steps considered in the seismic hazard analysis of Barcelona are described below.

Geology

The physical limits of the current city of Barcelona have been established with the help of four natural elements: the Mediterranean Sea, the Collserola mountain range, the Besós river and the Llobregat river (Figure 2). Most of the city is located on a plain, which has a gentle inclination towards the sea. On the other hand, from the geomorphological point of view it is possible to distinguish two units: a) the mountainous reliefs that constitute the substrate of the city and, b) the plain. In the case of mountainous reliefs, it is possible to find Paleozoic and Tertiary materials, while the Barcelona plain can be divided into two other geomorphological units: 1) the central area of the city, composed of Pleistocene old materials (2.5 Million years), and 2) the deltaic deposits of the Besòs and Llobregat rivers, which are composed of Holocena materials (0.012 Million years).

Figure 2. Satellite image of the city of Barcelona (ICC, 2010).

The Paleozoic materials of Barcelona are mainly composed of materials of sedimentary origin, affected by different degrees of metamorphism and plutonic materials. Particularly, there are limestones, blackboards and granites. The tertiary materials correspond to the Miocene that forms the Montjuïc block, and the most recent Pliocene, which constitutes the Quaternary substrate in the central area of the Eixample district and lower part of the city. The Miocene is formed by powerful marine series of shallow waters, with alternating layers of bluish loam banks, fossiliferous, greyish-red sandstone, and some level of conglomerates. While the Pliocene is constituted by a lower layer of blue-greenish marls, with numerous fossils, and an upper layer with sandy marls and brown-yellowish sands.

On the other hand, quaternary materials can be differentiated by their age in Pleistocene or Holocene. Pleistocene materials are basically formed by compact red clays, yellowish silt of wind origin and limestone crust. While the Holocene materials are deltaic deposits of the Besos and Llobregat rivers, formed by coarse sand and gravel, silt and intermediate clays, fine or coarse sand, brown plastic silt and humus soil (Cid et al, 2001). Figure 3 shows a map with the surface geological situation of Barcelona (Cid et al, 1999).

Figure 3. Geological situation, on the surface, of the city of Barcelona (Cid et al, 1999).

Seismogenetic Sources

Geometry of seismic sources

In the present work, the seismotectonic zones indicated in Figure 4 were considered (Secanell et al, 2004). These areas coincide with those used by Secanell et al (2004) and with minor modifications also coincide with those originally proposed by Goula et al (1997), which in turn have as reference the proposed seismotectonic zoning of Catalonia made by Fleta et al (1996). On the other hand, the seismotectonic zones used in this work have been used in various seismic hazard studies in Barcelona and Catalonia (Irizarry et al, 2010; Secanell et al, 2004; Irizarry et al, 2003a).

On the other hand, the geometry of each seismic source was defined in the CRISIS2008 program, using the data of longitude, latitude and depth, of each of the vertices of the polygon that represents each of the seismic sources.

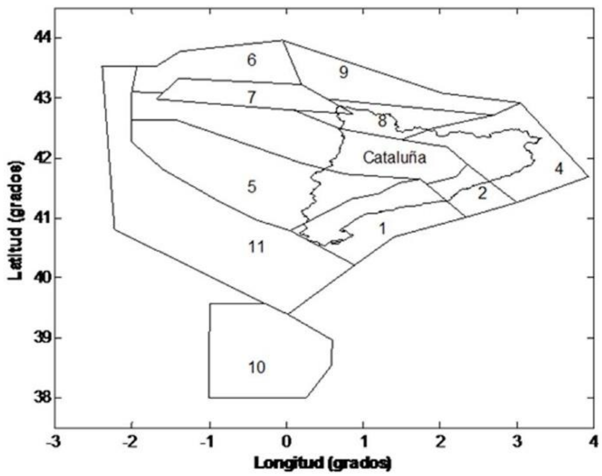


Figure 4. Geometric representation of the seismic sources used to estimate the seismic hazard of Barcelona.

Seismic potential

The seismicity of the seismic sources of Figure 4 was modeled using the truncated Gutenberg-Richter model, which is represented by Eq. 1.

$$\lambda(I) = \alpha \frac{e^{-\beta(I - I_{min})} - e^{-\beta(I_{max} - I_{min})}}{1 - e^{-\beta(I_{max} - I_{min})}} \quad (1)$$

Where λ *(I)* is the annual frequency of exceedance of the macroseismic intensity *I*, I_{min} is the minimum epicentral intensity considered, I_{max} is the maximum possible epicentral intensity in each zone, α is the annual frequency of exceedance of the intensities greater than or equal to I_{min} , and the value of β is the slope related to the Guttenberg-Richter law (Goula et al, 1997; Ordaz et al, 2008).

The seismicity parameters corresponding to each seismic source of Figure 4 are indicated in Table II. These parameters were determined from a seismic catalog based on MSK macroseismic intensities (Secanell et al, 2004), and have been used in recent studies of the seismic hazard of Barcelona and other regions of Catalonia (Irizarry et al, 2010; Secanell et al, 2004; Irizarry, 2004). For these reasons, the seismic parameters of seismic sources are used in this work.

Table 2 Seismicity parameters of the seismic sources, whose geometry is shown in Figure 4 (Secanell et al, 2004)

Zona Sismotectónica	Superficie (km^2)	α	σ (α)*	β	σ (β)*	h (km)*	I_{min}*	I_{max}*	I_{max} observada *
1	14100	0.100	0.030	1.864	0.559	7	V	VIII	VII
2	4600	0.128	0.033	1.608	0.324	7	V	IX	VIII
4	16300	0.157	0.030	1.256	0.186	10	V	X	IX
5	23100	0.040	0.014	1.319	0.373	10	V	IX	VIII
6	8000	0.099	0.025	1.977	0.640	10	V	VII	VI
7	7200	0.957	0.090	1.420	0.116	15	V	X	VIII
8	7700	0.218	0.040	1.716	0.246	15	V	IX	VIII
9	9600	0.070	0.020	1.737	0.214	10	V	VIII	VII
10	19700	0.635	0.059	1.201	0.083	10	V	XI	X
11	40100	0.060	0.016	0.886	0.242	10	V	IX	VIII

* σ (α) is the standard deviation of α; σ (β) is the standard deviation of β, h is the depth in km, I_{min} is the minimum epicentral intensity assigned to the seismic source; I_{max} is the maximum epicentral intensity assigned to the seismic source; I_{max} observed is the maximum epicentral intensity observed in the seismic source

Attenuation

Laws of attenuation of intensity

In this work, the laws of attenuation of López Casado et al (2000) were used. These laws were obtained mainly from catalogs of maps of isosistas of the Iberian Peninsula and are represented by Eq. 2.

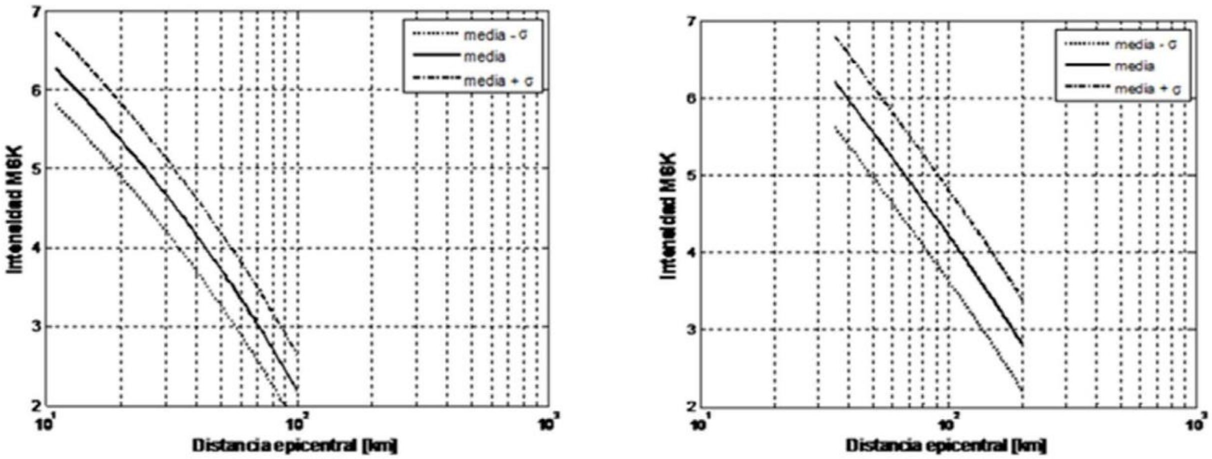
$$I = f\,(I_{epic})\; a_2 \ln\Delta - a_3\,\Delta \quad (2)$$

where I is the macroseismic intensity at a focal length Δ, $\Delta = (R^2\ R_0^2)^{1/2}$ with R the epicentral distance in km, and R_0 a value that is used to improve the fit and that has the meaning of focal depth in km (Table III); I_{epic} is the epicentral intensity on the MSK scale; f (I_{epic}) is determined according to Table III; a2 and a3 are coefficients that take the values indicated in Table III.

Table III Values corresponding to laws with high attenuation and low attenuation in the Iberian Peninsula according to López Casado et al (2000).

Attenuation	$f(I_{epic})$	a_2	a_3	R_0	σ
High (Figure 5a)	$6.016 + 0.090 \cdot I_{epic} + 0.069 \cdot I_{epic}^2$	1.477	0.01035	4	0.46
Low (Figure 5b)	$5.557 + 0.902 \cdot I_{epic} + 0.014 \cdot I_{epic}^2$	1.762	0.00207	2	0.59

σ is the standard deviation of macroseismic intensity *I*.



(a) (b)

Figure 5. Attenuation of the intensity of an earthquake with epicentral intensity VII, according to: (a) the "High" attenuation law and, (b) the "Low" attenuation law of López Casado et al (2000).

López Casado et al (2000) proposed a total of 5 mitigation laws, of which two are used in the present work. Each law of attenuation was defined according to the degree of attenuation, from a very high degree of attenuation to a very low degree of attenuation. In addition, they indicated the regions in which they consider each of the proposed attenuation laws to be valid. Based on the above and considering the location of the seismic sources used in this work, it was determined to use only two attenuation laws, the one corresponding to the low level of attenuation and the one corresponding to the high level of attenuation. Specifically, the low attenuation law is used for the seismic source 7 located in the Pyrenees region (Figure 4), and the high attenuation law is used for the rest of the seismic sources considered in this work.

Law of attenuation of maximum ground acceleration (PGA)

The seismic attenuation model chosen to estimate the seismic hazard of Barcelona in terms of the maximum acceleration of the terrain, is the one proposed by Ambraseys et al (1996). This attenuation law was obtained from seismic records of 157 earthquakes in Europe and adjacent regions (Ambraseys et al, 1996). On the other hand, this mitigation law was chosen in the Risk-UE project to estimate the seismic hazard of Barcelona, and has been considered an appropriate option to estimate the seismic hazard of the city (Irizarry et al, 2010). Additionally, the law of Ambraseys et al (1996) has been used to carry out previous seismic hazard studies of: a) regions of Catalonia (Perea and Atakan, 2007); b) of all of Catalonia (Irizarry, 2004), and; c) of the entire Iberian Peninsula (Jiménez et al, 2001). Curves due to the attenuation law of Ambraseys et al (1996) are shown in Figure 6.

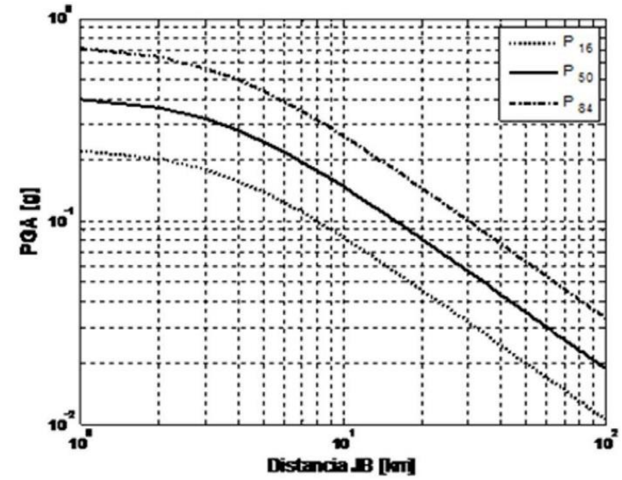


Figure 6. Attenuation curve of PGA values (g) vs. distance Joyner and Boore (1981), obtained by means of the equation of Ambraseys et al (1996), for a magnitude Ms = 6 and for a rock site.

Seismic hazard curve from macroseismic intensities

In the CRISIS2008 code it is possible to perform seismic hazard calculations by means of attenuation laws whose distribution of waste is normal. Thus, it is possible to integrate directly into the calculations, the uncertainty in the laws of attenuation of macroseismic intensity used for Barcelona. The latter is relevant, because in general, it is considered essential that the uncertainty in seismic attenuation laws be considered directly in the estimation of seismic hazard (Bommer and Abrahamson, 2006). Therefore, when considering in the CRISIS2008 the seismic sources of Figure 4, with their corresponding seismicity parameters, and the attenuation laws of Table III, it was possible to obtain the seismic hazard curve of Figure 7. According to said curve, the intensity of VI has a return period of 278 years, while the intensity of VII corresponds to a return period of 2041 years.

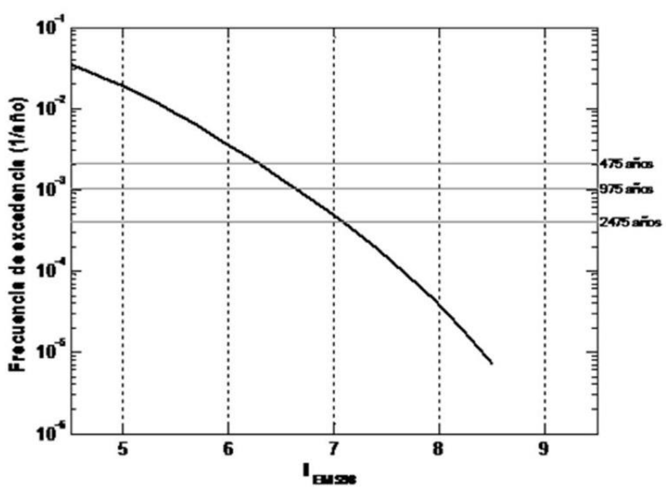


Figure 7. Seismic hazard curve of Barcelona obtained by means of the CRISIS2008 code, in which uncertainty was directly integrated into the laws of attenuation of macroseismic intensities.

Seismic hazard curve from the magnitude Ms

One of the difficulties of estimating the seismic hazard of Barcelona, through the seismicity of the seismic sources expressed in terms of seismic magnitudes, is that in such a case it is necessary to apply laws of transformation of macroseismic intensities to magnitudes M, for example, Ms magnitudes The use of such transformations is necessary because for the region of Catalonia, the most complete seismicity catalog for purposes of estimating seismic hazard is in terms of macroseismic intensities.

For this reason, three relations Magnitude (MS) - Epicentral intensity (I0) were used in this work. Additionally, the three relationships were taken into account by means of a logical tree and with this it was possible to obtain the seismic hazard curve shown in Figure 8.

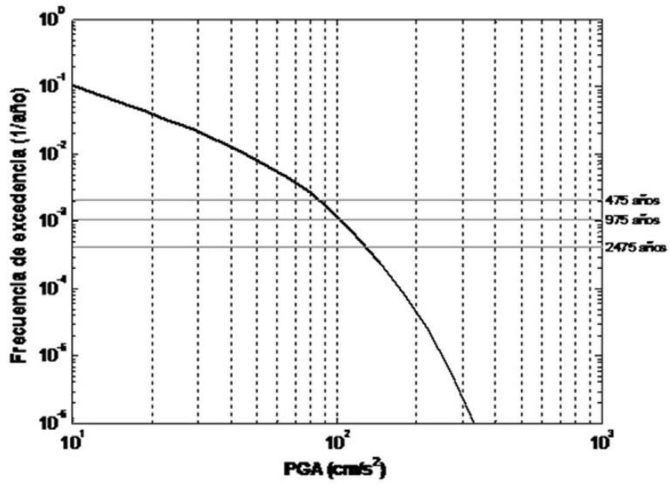


Figure 8. Seismic hazard curve of Barcelona obtained through CRISIS2008.

According to the seismic hazard curve of Figure 8, the PGA value that has a return period of 475 years is equal to 85 cm / s2. While the PGA value that has a return period of 975 years is equal to 102 cm / s2. On the other hand, in order to use these seismic hazard results in the estimation of seismic risk through the probabilistic method of vulnerability indices, it is necessary to convert this hazard curve (Figure 8), into another curve that is in terms of intensities macroseismic versus exceedance frequencies. For this purpose, it is possible to use PGA to MMI transformation laws.

Figure 9 shows 4 macroseismic-PGA intensity relationships: a) that of Sorensen et al (2008) that was proposed based on data from the Campania region in Italy and especially records of the 1980 Irpina earthquake; b) that of Wald et al (1999) determined from seismic data from California; c) that of Marin et al (2004) proposed based on data from France, and; d) that of the NCSE-94 standards. In this paper, the four relationships were used to observe the curves obtained in each case. Particularly, said relationships were used to transform the seismic hazard curve of Figure 8, and the curves of Figure 10 were obtained. For comparison purposes in Figure 10 the seismic hazard curve of Figure 7 is also included.

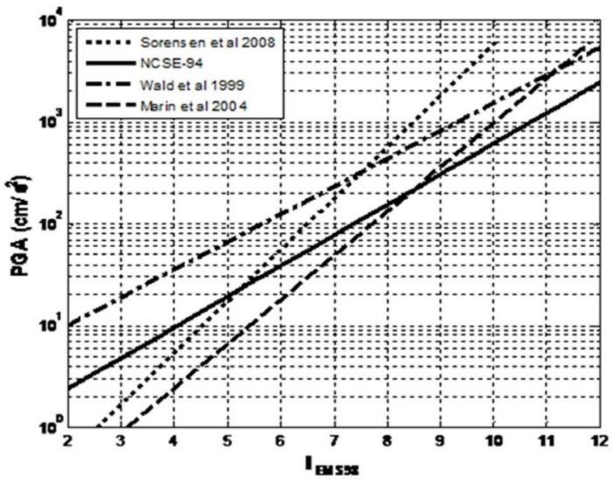


Figure 9. Macroseismic-PGA intensity relationships considered in this work.

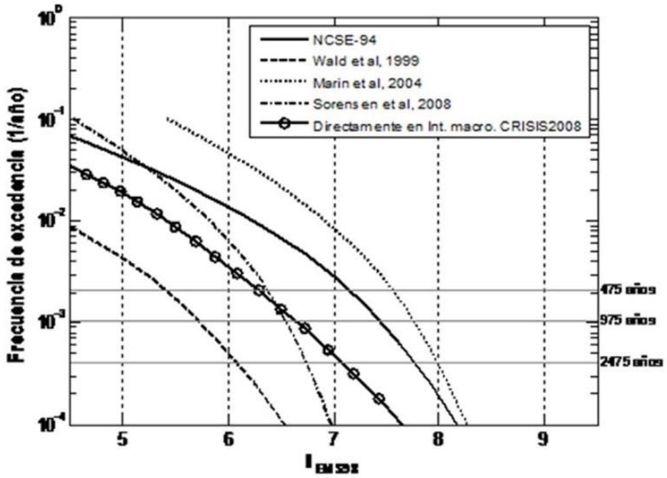


Figure 10. Comparison of the seismic hazard curves obtained by transforming PGA values into macroseismic intensities, with the seismic hazard curve obtained directly in terms of macroseismic intensities.

In Figure 10 it is possible to observe that among the curves in terms of macroseismic intensities obtained by transforming the curves in terms of PGA, the one obtained through the relationship of Sorensen et al (2008) is the one that has the greatest similarities to the curves of seismic hazard obtained directly in terms of macroseismic intensities. Especially, in the return periods between 475 years and 975 years. Therefore, because the seismic hazard curves obtained directly through macroseismic intensities, are those that accumulate less uncertainty, it is possible to conclude that for the present study the Sorensen relationship is a reasonably adequate relationship for the case of Barcelona, especially, at macroseismic intensities between V and VII. Therefore, the frequency curve of excess of macroseismic intensities obtained by transforming by means of the relationship of Sorensen et al (2008), the frequency curve of excess of PGA values of Figure 8, can be considered a curve that represents in shape reasonable the seismic hazard of Barcelona.

It is important to note that the seismic hazard results obtained in this study have important coincidences with the seismic hazard results obtained in previous studies, both in the case of results in terms of macroseismic intensities (Secanell et al, 2004; Peláez and López, 2002; Goula et al, 1997; NCSE-02, 2002) as in the case of results in terms of PGA (Jiménez et al, 1999; Peláez and López, 2002; Irizarry et al, 2010; Secanell et al, 2008; NCSE -02, 2002).

Seismic hazard

Seismic hazard curves in terms of macroseismic intensities versus surplus frequencies can be used to estimate seismic hazard using the probabilistic methodology of vulnerability indices. By doing so for the city of Barcelona, and particularly for 68982 residential buildings in the city, it is possible to obtain for each building seismic hazard curves such as those shown in Figure 11. By averaging the results obtained, it is possible to obtain seismic hazard results for all of the buildings in Barcelona studied. According to these latest results, the district with the highest seismic hazard in the city is that of Ciutat Vella. It is also possible to conclude that the seismic hazard of some buildings in Barcelona is important, because although these buildings are located in areas with moderate levels of seismic danger, they have very high levels of seismic vulnerability.

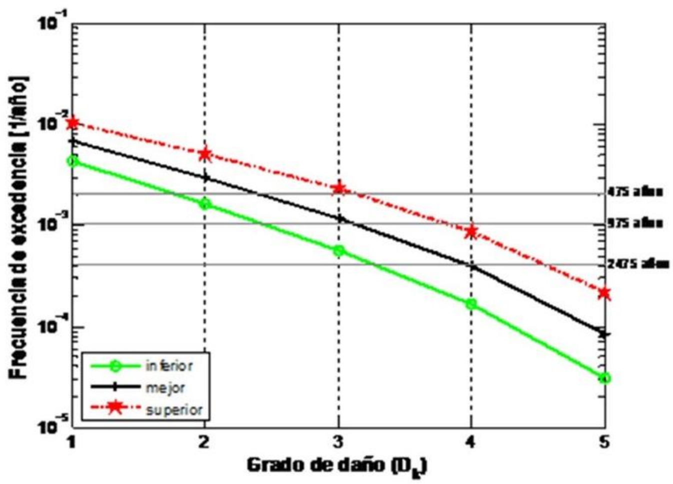


Figure 11. Seismic risk curves of a building in Barcelona, obtained by applying the probabilistic methodology of vulnerability indices (Aguilar, 2011) and considering the seismic hazard curve of Barcelona.

Conclusions

The estimation of the seismic danger of Barcelona implies important challenges because the city is located in a region of seismicity between moderate and low. For this reason, using a probabilistic methodology to estimate the seismic danger of Barcelona is one of the best alternatives, to identify the seismic danger of the city.

The code CRISIS2008 allowed to estimate the seismic danger of Barcelona, directly in terms of frequencies of excess of the macrosismic intensities. For example, according to the results, in Barcelona the intensity of VI has an average return period of 278 years. Similarly, it was obtained that the intensity that in Barcelona has an average return period of 475 years is equal to 6.3 (VI-VII).

The seismic risk of Barcelona should not be ignored because, according to the results, the levels of seismic vulnerability of some buildings are very high, and therefore, the respective levels of seismic risk are also important.

Acknowledgments

This work has been partially supported by:
1) The Spanish Ministry of Education and Science and with ERDF funds (project: CGL-2005-04541-C03-02 / BTE);
2) The project "Seismological, geophysical and engineering contributions to the prediction and prevention of seismic risk" (CGL2008-00869 / BTE);
3) The European Commission and with ERDF funds through the research project "SisPyr: INTERREG: POCTEFA 2007- 2013/73/08";
4) PROMEP Project: "Sensitivity analysis in the probabilistic estimation of seismic hazard in regions, and evaluation of the CRISIS2008 code used to calculate the seismic hazard."

The first author recognizes the valuable support of the University of Veracruz, of the Engineering Institute of the UNAM and the Polytechnic University of Catalonia.

References

Aguilar, A., 2011. Probabilistic evaluation of the seismic risk of buildings in urban areas, Directors: Alex H. Barbat, Lluis G. Pujades and Mario G. Ordaz. Doctoral thesis. Polytechnic University of Catalonia. Barcelona.

Ambraseys, N. N., Simpson, K. A., Bommer, J. J., 1996. Prediction of horizontal response spectra in Europe, Earthquake Engineering and Structural Dynamics, 25: pp. 371-400.

Bommer, J. J., Abrahamson, N. A., 2006. Why Do Modern Probabilistic Seismic-Hazard Analyzes Often Lead to Increased Hazard Estimates?, Bulletin of the Seismological Society of America, 96 (6): 1967-1977.

Casas-Sainz, A. M., De Vicente, G., 2009. On the tectonic origin of Iberian topography; Tectonophysics; 474: 214-235.

Cid, J., Figueras, S., Fleta, J., Goula, X., Susagna, T., Amieiro, C., 1999. Seismic Zoning of the City of Barcelona. First National Congress of Seismic Engineering, Murcia, Spain, pp. 263-271.

____, J. Susagna, T., Goula, X., Chavarria, L., Figueras, S., 2001. Seismic Zonation of Barcelona Based on Numerical Simulation of Site Effects; Pure and Applied Geophysics; 158: pp. 2559-2577.

Cornell, A., 1968. Engineering Seismic Risk Analysis, Bulletin of the Seismological Society of America, 58, (5): pp. 1583-1606.

Esteva, L., 1970. Seismic regionalization of Mexico for engineering purposes. Institute of Engineering, Series-246, UNAM, Mexico.

Fleta, J., Escuer, J., Goula, X., Olivera, C., Combes, Ph., Grellet, B., Granier, Th., 1996. Tectonic zoning, first stage of the seismotectonic zoning of the NE of the Iberian Peninsula (Catalunya), Geogaceta, 20 (4): pp. 853-856.

_____, J., Estruch, I., Goula, X., 1998. Geotechnical characterization for the regional assessment of seismic risk in Catalonia. Proceedings 4th Meeting of the Environmental and Engineering Geophysical Society, Barcelona, pp. 699-702.
Goula, X., Susagna, T., Secanell, R., Fleta, J., Roca, A., 1997. Seismic Hazard Assessment for Catalonia (Spain). Proceedings Second Congress on Regional Geological Cartography and Information Systems, Barcelona, pp. 173-177.
Grünthal, G., 1998. European Macroseismic Scale 1998. Cahiers du Centre Européen de Géodynamique et de Séismologie. Luxemburg; 15: pp. 1-99.
ICC, 2010. Cartographic Institute of Catalonia. http://www.icc.es/vissir2/?lang=ca_ES (Accessed December 18, 2010).
Irizarry, J., Goula, X., Susagna, T., 2003a. Analytical formulation for the elastic acceleration-displacement response spectra adapted to Barcelona soil conditions. Technical report Barcelona: Institut Cartogrà c de Catalunya.
Irizarry, J., Goula, X., Susagna, T., 2003b. Evaluation of the seismic danger of the city of Barcelona in terms of spectral acceleration, 2nd National Congress of Seismic Engineering, Malaga, Spain, pp. 389-399.
Irizarry, J., 2004. An Advanced Approach to Seismic Risk Assessment. Application to the Cultural Heritage and the Urban system of Barcelona. Doctoral thesis, Polytechnic University of Catalonia, Barcelona, 406 pp.
_____, J., Lantada, N., Pujades, LG, Barbat, AH, Goula, X., Susagna, T., Roca, A., 2010. Ground-shaking scenarios and urban risk evaluation of Barcelona using the Risk-UE capacity spectrum based method; Bulletin of Earthquake Engineering (9) 2: 441-466.
Jabaloy, A., Galindo-Zaldívar, J., González-Lodeiro, F., 2002. Palaeostress evolution of the Iberian Peninsula (Late Carboniferous to present-day); Tectonophysics 357: pp. 159-186.
Jiménez, M-J., García-Fernández, M., GSHAP Ibero-Maghreb Working Group, 1999. Seismic hazard assessment in the Ibero-Maghreb region; Annali di Geo sica, 42 (6): pp. 1057-1065.
_____, M.J., Giardini, D., Grünthal, G., SESAME Working Group, 2001. Unified seismic hazard modeling throughout the Mediterranean region, Bollettino di Geofisica Teorica ed Applicata, 42 (1-2): pp. 3-18.
Joyner, W. B., Boore, D. M., 1981. Peak horizontal acceleration and velocity from strong-motion records including records from the 1979 Imperial Valley, California, earthquake; Bulletin of the Seismological Society of America, 71 (6): pp. 2011-2038.
López Casado, C., Molina, S., Delgado, J., Peláez, J. A., 2000a. Attenuation of Intensity with Epicentral Distance in the Iberian Peninsula; Bulletin of the Seismological Society of America; 90: pp. 34-47.
Marin, S., Avouac, J-P., Nicolas, M., Schlupp, A., 2004. A probabilistic approach to seismic hazard in metropolitan France; Bulletin of the Seismological Society of America, 94 (6): pp. 2137-2163.
Musson, R.M.W., Cecic, I., 2002. Macroseismology. In W. HK Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (Eds). International Handbook of Earthquake & Engineering Seismology, Volume 81A, pp. 807-822.
NCSE-02, 2002. Earthquake Resistant Construction Standard: General and Editing Part, Royal Decree 997/2002, Official State Gazette No. 244, Madrid.
NCSE-94, 1994. Seismic-resistant Construction Standard: General and Building Part, Royal Decree 2543/1994, Official State Gazette No. 33, Madrid.

Ojeda, A., Atakan, K., Masana, E., Santanach, P., Jiménez, MJ., García Fernández, M., 2002. Integration and influence of paleoseismic and geologic data for the seismic hazard evaluation in the Catalan coastal ranges, Spain; Soil Dynamics and Earthquake Engineering 22: pp. 911-916.
Olivera, C., Redondo, E., Lambert, J., Riera, A., Roca, A., 2006. The earthquakes of the XIV and XV centuries in Catalonia (NE Spain). First European Conference on Earthquake Engineering and Seismology . Geneva, Switzerland, 10 pp.
Ordaz, M., Martinelli, F., Aguilar, A., Arboleda, J., Meletti, C., D’Amico, V., 2008. CRISIS2008, See 3.8. Program for computing seismic hazard, UNAM, Mexico.
Peláez, J. A., López, C., 2002. Seismic Hazard Estimate at the Iberian Peninsula; Pure and Applied Geophysics; 159: pp. 2699-2713.
Perea, H., Atakan, K., 2007. Influence of slow active faults in probabilistic seismic hazard assessment: the northwestern margin of the València trough; Natural Hazards, 43: pp. 379-396.
Rosenbaum, G., Lister, G. S., Duboz, C., 2002. Relative motions of Africa, Iberia and Europe during Alpine orogeny; Tectonophysics; 359: pp. 117-129.
Secanell, R., 1999. Valuation of the seismic perillositat to Catalonia: analysis of sensitivities per a differents models d’ocurrència I paràmetres seísmics, PhD thesis, University of Barcelona, Barcelona, 335 pp.
_____, R., Goula, X., Susagna, T., Fleta, J., Roca, A., 1999. Map of seismic areas of Catalonia. 1st National Congress of Seismic Engineering, Murcia, Spain, pp. 251-259.
_____, R., Goula, X., Susagna, T., Fleta, J., Roca, A., 2004. Seismic hazard zonation of Catalonia, Spain, integrating random uncertainties, Journal of Seismology, 8: pp. 25-40.
_____, R., Bertil, D., Martin, C., Goula, X., Susagna, T., Tapia, M., Dominique, P., Carbon, D., Fleta, J., 2008. Probabilistic seismic hazard assessment of the Pyrenean region. Journal of seismology, 12: pp. 323-341.
Sorensen, M. B., Stromeyer, D., Grünthal, 2008. Estimation of macroseismic intensity-New attenuation and intensity vs. ground motion relations for different parts of Europe. Proceedings of the 14th World Conference on Earthquake Engineering, Beijing, China, October 12-17, 8 pp.
Susagna, M. T., Goula, X., 1999. Atles Sísmic de Catalunya. Volum 1: Seismicitat catalog. Institut Cartogràfic de Catalunya, Barcelona, 413 pp.
Wald, D. J., Quitoriano, V., Heaton, T. H., Kanamori, H., 1999. Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modi ed Mercalli Intensity in California; Earthquake Spectra, 15 (3): pp. 557-564.

Chapter 4

Seismic monitoring techniques applied to Citlaltepetl: some results

Ana María Alarcón Ferreira
Francisco Córdoba Montiel
Ignacio Mora González
Sergio R. Rodríguez Elizarrarás

Abstract (Translated)

The relationship between the presence of volcanoes, the regional tectonic framework and dynamics of earthquakes is very narrow (Burski, 2008). In Veracruz the active volcanism is located in the Mexican Volcanic Belt, originated by the subduction processes between the North American plate and the Rivera and Cocos plate and in the Tuxtlas Volcanic Field (TVF), where Verma (2006) suggests that magmatism of the TVF is similar to those found in magmas of rift zones (outreach efforts) but further studies are required to better understand its origin (Espíndola, 2010).

In the Citlaltepetl volcano in the last 467 years, an eruption has occurred with VEI = 2 on average every 78 years, and the probability of one occurring in the next 50 years is 0.48. These figures only try to give an idea of the order of the probabilities. Each case must be analyzed in the context of the eruptive history of the volcano in question. The analysis of the patterns of occurrence of an explosive eruption will help to make quantitative estimates of threat levels (Basic Guide, 2006).

In addition, there are records of the collapse of the building approximately 13,000 years ago, which generated a gigantic avalanche of rubble that traveled 80 km away and covered an area of 140 km^2 with a volume of 1.8 km^3. The presence of a glacier and a hydrothermal system caused alteration of the rock making it less competent. These conditions also exist today in the volcano. Thus, the potential risk of collapse of the edifice could generate a large volume lahar. In the year 1920 and as a result of an earthquake Ms = 6.2 (Suter et al., 1996), a debris flow of 44 million m^3 was generated.

Most eruptions, perhaps all, are preceded by geophysical and / or geochemical changes in the state of the volcano; Therefore, it is necessary to establish a volcanic surveillance, which refers to the scientific studies that systematically observe, record and analyze the visible or invisible changes that occur in the volcano and its surroundings. These changes can be detected and measured through instrument networks and the use of specialized techniques (Tilling, 1989).

Seismic and deformation monitoring methods are used for systematic measurements and diagnostic interpretation of the behavior models of volcanic activity. Measurements of variations in seismicity and soil deformation have provided reliable data and are widely used in volcano monitoring (Tilling, 1989). Additionally, other monitoring methods such as spring geochemist and visual have been incorporated.

This work will present the techniques used and the results derived from the seismic monitoring of the Citlaltepetl volcano and instrument growth in this volcano.

Original abstract from book.

The relationship between the presence of volcanoes, the regional tectonic framework and dynamics of earthquakes is very close. There is a close connection between the presence of volcanoes, the regional tectonic framework and dynamics of earthquakes. In Veracruz active volcanism is located in the Mexican Volcanic Belt, caused by the subduction of two plates: North American and Cocos and in the Tuxtlas Volcanic Field (TVF), where according to Verma (2006) CVT magmatism is similar to the magmas typical of rift zones (extension-related) but more studies are required to better understand their origin.

During the last 467 years of the eruptive history of Citlaltépetl volcano, there has been a VEI = 2 eruption on average every 78 years, and the probability of another eruption of this type in the next 50 years is 0.48 (according to simple probabilistic estimations). Nevertheless, each case must be analyzed individually in the context of the eruptive history of the volcano in question. The analysis of the recurrence rate of an explosive eruption will help make quantitative estimates of the threat levels.

In addition, there are records of events including volcanic edi ce collapse:

~ 13,000 years: a gigantic avalanche debris, travelled 80 km from the source, covered an area of 140 km^2 and had a volume of 1.8 km^3. The presence of a glacier and a hydrothermal system altered the rock to be less competent, increasing collapse probability; The same conditions also exist today. The potential risk of volcanic edifice collapse could generate large volume lahars. In 1920 a debris ow of 44 million m^3 was triggered by an earthquake (Ms-6.2).

An avalanche of a slightly larger volume would be able to threaten Coscomatepec population, and if the avalanche would move along the Metlac drainage system, the city of Orizaba would probably be affected. The city lies on the banks of the river Orizaba; calculations indicate that the height of the wave of debris could reach 16m.

Most eruptions, perhaps all, are preceded by geophysical and/or geochemical changes of the volcano state, which creates the necessity to establish a volcano monitoring, which refers to scientific studies that observe, record and analyze systematically the visible or invisible changes that occur in the volcano and its surroundings. Such changes can be detected and measured by instrument networks and the use of specialized techniques.

Seismic monitoring and deformation methods are used for systematic measures and diagnostic interpretation of behavior patterns of volcanic activity. Measurements of changes in seismicity and ground deformation data have provided reliable and are widely used in monitoring volcanoes. Additionally, other methods have been incorporated as for example geochemical and visual monitoring of springs.

This paper presents the techniques and results derived from seismic monitoring of Citlaltepetl volcano from its beginning, and the activities designed to modernize instruments, as well as the incorporation of other monitoring techniques.

History and geological construction of the Citlaltepetl volcano

In Veracruz the active volcanism is located in the Mexican Volcanic Belt, originated by the subduction processes between the North American plate and the Rivera and Cocos plate, and in the Tuxtlas Volcanic Field (TVF), where Verma (2006) suggests that the magmatism of the TVF is similar to the magmas found in rift zones (extension efforts), however, more studies are required to better understand its origin (Espíndola, 2010). The Citlaltepetl or Pico de Orizaba volcano is located at 19 ° 01’N, 97 ° 16’W with a height of 5,675 meters, within the Mexican Volcanic Belt. Citlaltepetl means "Star Hill" in Nahuatl. The current cone is mainly composed of andesitic and dacitic lavas.

The last important activity occurred in 1687 (Mooser, et al., 1958), although there are reports of minor eruptions in more recent times (De-la Cruz and Carrasco-Núñez, 2002). There are signs of modern seismic activity such as weak exhalations of SO_2, earthquakes called volcanotectonics and sulfur deposits in the crater walls (Waitz, 1910-1911), which is why it is considered an active volcano in a state of stillness.

The first regional geological studies were conducted by Yañez-García and García-Durán (1982) and Negendank et al. (1985). In 1982 Robin and Cantagrel presented the first work on the stratigraphy and evolution of Citlaltepetl, which was followed by more detailed studies (Hoskuldsson, 1992; Carrasco-Núñez, 1993).

Petrological studies were conducted in the 1980s (Kudo et al., 1985; Singer and Kudo, 1986; Calvin et al., 1989). Studies related to eruptive activity have been performed by (Cantagrel et al., 1984; Hoskuldsson et al., 1990; Hoskuldsson and Robin, 1993; Carrasco-Núñez, 1993; Carrasco-Núñez, 1993; Siebe et al., 1993 ; Carrasco-Núñez and Rose, 1995; Carrasco-Núñez, 1997; Gómez-Tuena and Carrasco-Núñez, 1999; Rossotti and Carrasco-Núñez, 2004) and the first geological map of the volcano is made with the description of its different stages of training (Carrasco-Núñez and Ban, 1994; Carrasco-Núñez, 2000).

Based on a detailed stratigraphic study Carrasco-Núñez and Ban (1994) and Carrasco-Núñez (2000), they concluded that the construction of the volcano had occurred in four eruptive phases, the stages of evolution of the Citlaltepetl were named from the oldest to the most Recent: the Torrecillas cone, the Espolón de Oro cone, peripheral silicon domes and the Citlaltepetl cone (Carrasco-Núñez and Ban, 1994; Carrasco-Núñez, 2000).

The formation of the Citlaltepetl cone is not only linked to the occurrence of effusive eruptions, but also to the occurrence of explosive eruptions (Siebe et al., 1993; Hoskuldsson and Robin, 1993; Carrasco-Núñez and Rose, 1995; Rossotti and Carrasco- Nunez, 2004).

With all the geological information existing in 2002, Sheridan and collaborators prepared the volcanic hazard map of the Citlaltepetl and with the use of the FLOW3D (Kover, 1995) and LAHARZ (Iverson et al., 1998) programs. Díaz-Castellón (2003) and Zimbelman et al. (2004) evaluated the stability of the volcanic building (figure 1). In addition, Sheridan et al. (2004) reassessed the zoning for pyroclastic eyes of the Citlaltepetl and presented in detail the methodology used to prepare the hazard map for this volcano.

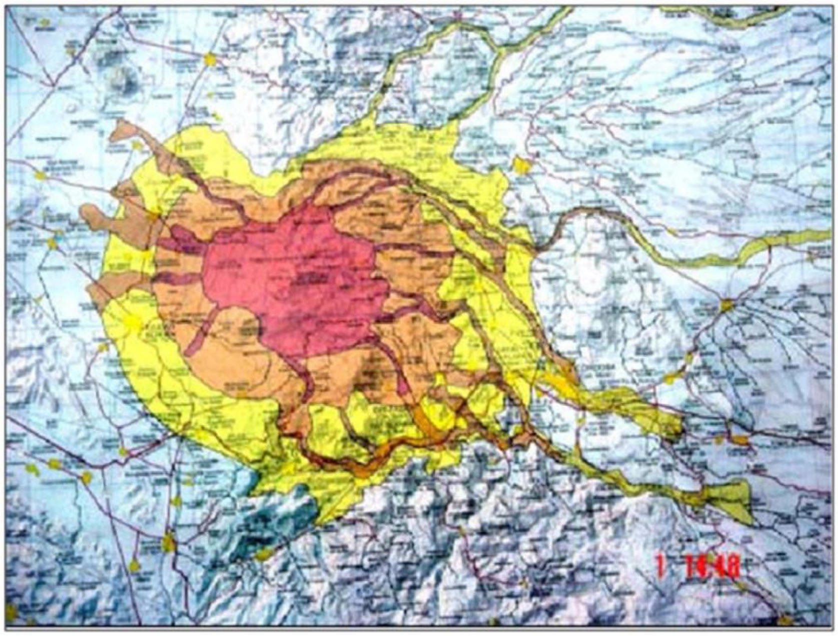


Figure 1. The map can be very useful in the design of economic and social development plans, as well as civil protection plans, in case of contingency since the areas that could be affected are indicated, in Veracruz there are 20 municipalities and in Puebla are 12. Around 700, 000 people in less than 50 Km radius.

Volcanic Hazard Assessment

The "danger" or "threat" is related to the possible occurrence of a physical phenomenon of natural origin, which can manifest itself on a site and during a predetermined exposure time. Due to the complexity of the physical systems in which a large number of variables can condition the process, science does not yet have techniques that allow it to model such systems with high precision and therefore the mechanisms generating each of the threats.

For this reason, the threat assessment, in most cases, is done by combining the probabilistic analysis with the analysis of the physical behavior of the generating source, using information from events that have occurred in the past and modeling with some degree of approach to the physical systems involved.

The magnitudes are obtained from the Volcanic Explosivity Index (VEI) (figure 2), which represents a measure of the total energy that releases an eruption and the rate at which that energy is released (λ). The eruptive rate is the average rate at which eruptions of a certain magnitude or range of magnitudes have occurred (Figure 3) in time λ (VEI). The inverse of this parameter is the average recurrence time for that type of eruptions τ (VEI) = 1 / λ (VEI). In general terms, there is a certain correlation between the VEI and the destructive potential that an eruption may have.

This correlation is not very precise, since sometimes eruptions with low or moderate VEI values can be very harmful. However, eruptions with high VEI tend to always be destructive to the environment of the volcanoes that originate them.

VEI	0	1	2	3	4	5	6	7	8
Description	Non explosive	Small	Moderate	Moderate-Large	Large	Very Large	--	--	--
Volume issued (m^3)	<10,000	10,000-1,000,000	One to ten million	Ten to a hundred million	One hundred to a billion	One to ten km^3	Ten to one hundred km3	One hundred to one thousand km^3	More than $1000km^3$
Height of the column (km)	0,1	0,1-1	1-5	3-15	10-25	More than 25	--	--	--
Duration in hours	-1	-1	1-6	1-6	1-12	6-12	More than 12	--	--
Injection into the troposphere	Minimum	Mild	Moderate	Substantial	Large	--	--	--	--
Injection into the stratosphere	Null	Null	Null	Possible	Defined	Significative	Large	--	--

Adapted from Newhall and Sef (1982)

Figure 2. Composite scale that considers various characteristics of an explosive eruption. Volcanic Explosivity Index (VEI) of Newhall and Sef (1982).

Probability of hazard occurrence

For the purposes of hazard analysis, volcanoes are classified according to criteria related to their eruptive rates and the magnitudes (VEI) that have been able to produce, this definition of magnitude continues to be adjusted.

	Year	VEI
Historical	1867	2
	1846	2
	1687	2
	1569–89	2
	1545	2
	1533–39	2
	Year BP	VEI
Geological	4100	≥4
	8500–9000	≥4
	13000	≥4

Figure 3. Geological and historical activity recorded in the Citlaltepetl volcano (De la Cruz-Reyna and Carrasco-Núñez, 2002).

In the section on Volcanic Hazard Maps of the Basic Guide for the Preparation of State and Municipal Atlases of Hazards and Risks (2006), proposed and published by CENAPRED, it is mentioned that the probability of occurrence of at least one eruption of VEI 2 and 4 in the Citlaltépetl volcano over the next 50 years, can be obtained using a Binomial distribution, under the assumption that the Bernoulli process describes the volcanic stationary eruptive sequence.

Using the binomial statistical distribution $B(n, x) = C_x P^x (1- P)^{n-x}$, it is obtained that in the Citlaltépetl volcano in the last 467 years, an eruption has occurred with VEI = 2 on average every

78 years, and the probability of one occurring in the next 50 years is 0.48. These figures only try to give an idea of the order of the probabilities.

Each case must be analyzed in the context of the eruptive history of the volcano in question. The analysis of the patterns of occurrence of an explosive eruption will help to make quantitative estimates of threat levels.

Seismic monitoring on the Citlaltepetl volcano

Most eruptions, perhaps all, are preceded by geophysical and / or geochemical changes in the state of the volcano, so it is necessary to establish volcanic surveillance that refers to scientific studies that systematically observe, record and analyze visible changes or invisible that occur in the volcano and its surroundings. These changes can be detected and measured through instrument networks and the use of specialized techniques (Tilling, 1989). Seismic and deformation monitoring methods are used to perform systematic measurements and diagnostic interpretation of the behavior models of volcanic activity. Measurements of variations in seismicity and soil deformation have provided reliable data and are widely used in volcano monitoring (Tilling, 1989). Additionally, other monitoring methods such as spring geochemical and visual have been incorporated.

Ibáñez, 2000 mentions that the analysis of the data of a seismic network will allow to know different aspects of the volcanic system such as: the dynamics and transport of fluids, the effects or consequences of that dynamics and the possible state of local and regional efforts (source mechanisms seismic), also provide information on many aspects such as the parameters of the source (position, temporal evolution, energy quantification, physical and nature) and the environment (speed structure, attenuation, local response, heterogeneities, etc.) In the case of the Citlaltepetl volcano, the application of seismic monitoring has been carried out since 1999, through the analysis of seismic records obtained from the operation of the stations located in the volcano.

In addition, Ibáñez (2000) mentions that to carry out the study and analysis of a volcanic region using seismic data, it is required:

- Detection, recording and acquisition of seismic signals.
- Identification, characterization and classification of seismic signals.
- Quantitative analysis of seismicity.

The three previous points are listed below, relating them to the Citlaltepetl volcano.

Detection and recording of seismic signals

In Mexico, only the Popocatepetl and Fuego de Colima volcanoes have real-time seismic networks, which have recorded seismic activity and, together with other monitoring data, have allowed studies on volcanic seismicity that have been used to prepare forecasts for short, medium and long term (Macías, 2005).

In the state of Veracruz there are volcanoes and volcanic fields, of which the Citlaltepetl volcano (Pico de Orizaba) stands out, located in the eastern part of the Mexican Volcanic Belt and the San Martín Volcano, located in the Tuxtlas Volcanic Field, both are considered active volcanoes and therefore need to be monitored.

For real-time seismic monitoring of the Citlaltepetl volcano, the Center for Earth Sciences of the University of Veracruz (CESUV) and the National Center for Disaster Prevention (CENAPRED) began the work of seismic instrumentation through the installation of a seismic network composed of three stations with an approximately triangular distribution. In March 1998, the first seismic station was installed on this volcano called Halcon (POHV), of analog type and consists of a Mark L4C uniaxial short period seismometer with a natural frequency of 1 Hz.

In June of 2001 CESUV in collaboration with CENAPRED, civilian staff from Puebla and Veracruz and the BUAP, installed the second analog seismic station that received the name Chipe that includes a Mark L4C short-term triaxial sensor and in 2004 CCTV, CENAPRED and Protection personnel Civil Veracruz, installed the third analogue station called Halcon II that operates with a 1 Hz Mark L4C uniaxial seismometer.

The three stations are autonomous and send their signals to the Central Post of the Registry of the Center for Earth Sciences of the University of Veracruz (Figure 4) in Xalapa and to CENAPRED through telemetric links.

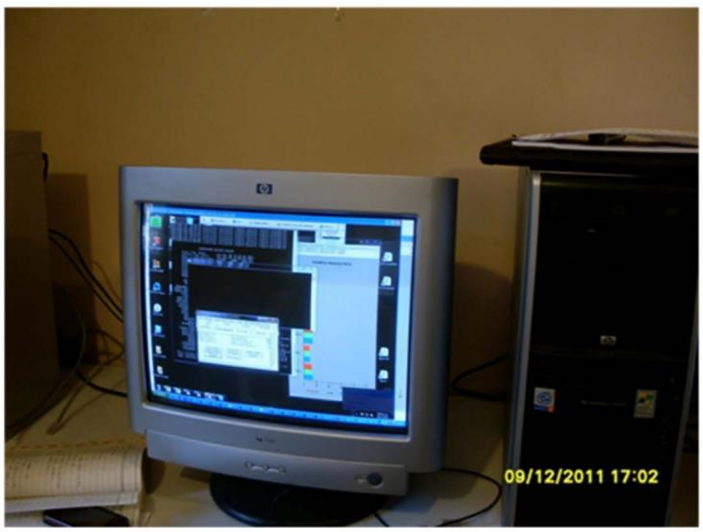


Figure 4. The Earthworm 7.5 data acquisition system records and stores data from short-term seismic stations located in the Citlaltepetl volcano. (Photo: A. Alarcón).

The records of the seismic station of Ciudad Serdán (IIS) of the Engineering Institute of the UNAM have also been used.

Identification, characterization and seismic classification

Active volcanoes are sources of a wide variety of seismic signals, which have been classified according to their waveform, spectral content and / or location. However, the current trend is to improve the understanding of the effects of the source and propagation, since this gives a much more complete criterion for the classification of a signal, as suggested by Ibáñez (1997), when stating that such variations in the classification depend largely on the type of instrument, geological conditions and the type of volcano.

A concrete example can be seen in works such as that developed by Hidayat et al. (2000) in the Merapi Volcano (Indonesia) where they find that events that have low frequencies at stations 3 and 5 km from the crater, appear with high frequencies at stations located 200 and 300 m from it (note here a strong effect of propagation).

For this reason, various classifications have been proposed by authors (Table I), such as Okada et al. (1981) who found at least eight types of events in the Usu Volcano (Japan). In addition, they observed that, for sources separated about 200m from each other, different signals appeared, suggesting variations in the source, rather than a propagation effect. Another example of several signals is given by Malone et al. (1981) and Malone et al. (1983) who described six types of signs in St. Helens Volcano (USA).

The frequency content of some of these signals varied from one station to another, suggesting propagation effects, although differences in the spectral content were also observed for the same position, indicating different behavior of the source. On the other hand, it is possible that the lack of a global terminology critically hinders the assignment of a specific name to a given type of earthquake.

The seismic classification criteria mentioned in Table I have also been applied to the Popocatepetl volcano for the classification of its seismic events. In the case of the Citlaltepetl volcano, the seismic network that has operated from 1999 to 2012 has registered seismic events of Type A called volcanotectonics and small landslides.

Molina (1999) Tungurahua Volcano (Adopts Power's)	Minakami (1960,1974) Asama and Sakurajima Volcanoes Dibble (1974) Ruapehu(a)	Latter(b) (1979,1981) Ruapehu and Ngauruhoe Volcanoes Ntepe and Dorel (1990) Stromboli	Power et al (1994) Redoubt Volcano	McNutt et al (1996) Mammoth Mountain	Other kinds Mount St. Helens, Nevado del Ruiz Volcano, Soufriere Hills
Volcano-Tectonic (VT)	Type A	Volcano-Tectonic	Volcanotectonic VT	High Frequency HF	High Frequency (Endo et al., 1981; Nieto et al., 1990), Type H (Malone et al., 1983)
Long Period (LP)	Type B	Volcanic	Long period	Low Frequency LF	Low Frequency (Endo et al., 1981). Type M and Type L (Malone et al., 1983). Long period (Nieto et al., 1990)
Hybrid (HB)	--	--	Hybrid	Mixed Frequency	Hybrid (White, R., 1998). Medium Frequency
Volcanic Tremor	Volcanic Tremor	Volcanic Tremor (low, medium and high frequency)	Volcanic Tremor	Volcanic Tremor	Harmonic tremor, spasmodic tremor

Table I. Seismic classification applied to various volcanoes in the world.

Type A or Volcanotectonic Events

Volcanotectonic events are generated by failure or fractures of cut in solid rocks, such as those caused in subduction zones. Its main characteristics are detection of the arrival of P and S wave packets, a short intense phase, as well as the contribution of surface waves and a final decay in the form of decreasing exponential that represents the coda. The frequencies are defined for these earthquakes range between 5 and 15 Hz and their hypocentral depths vary between 3 and 10 km.

Type A or volcanotectonic events have been registered in the Citlaltépetl volcano from 1999 to 2012; Figure 5 (a) corresponds to a volcanotectonic earthquake recorded on December 29, 2003 and Figure 5 (b) to another occurred on August 31, 2006.

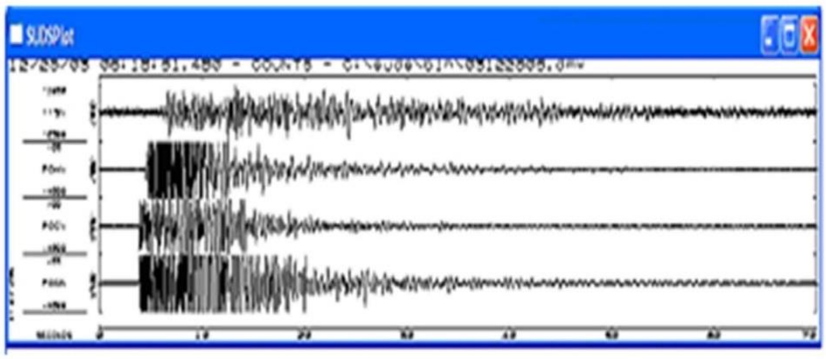


Figure 5(a)

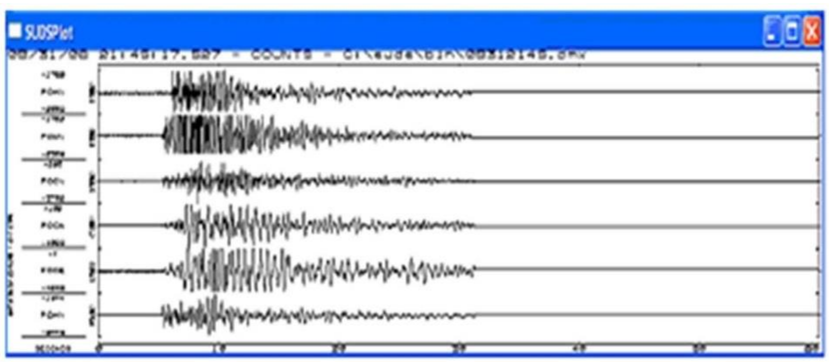


Figure 5(b)

The volcanotectonic earthquakes that have been located by their first clear arrivals at the POHV, POC and IISV stations are presented in Table II using the HYPOCENTER program of Lienert et al. (1986). This program, based on HYPO71 (Lee and Lahr, 1975) presents better solutions by allowing depth to behave as a variable throughout the iterative process. In addition, this program uses statistical regression procedures such as centering and scaling to improve the condition matrix, which relates the changes in arrival times to variations in the hypocentral location.

HYPOCENTER uses a flat layer velocity model. Although it is difficult to think that such a model is realistic for a volcanic edifice, it must be taken into account that this structure has been built in layers. Such a model will essentially behave as a single layer, since seismic rays with wavelengths of 0.35-3 km will not be affected by layers of thicknesses smaller than these dimensions. The model used (Mikumo, personal communication) for the locations in the

Popocatepetl volcano consists of a layer of 3.5 km thick from the top of the volcano and with a speed of 3.5 km / s. The second layer has a thickness of 4.5 km and a speed of 5.5 km / s. The last layer consisting of a half space has a speed of 6.5 km / s. Speeds were determined using the ratio /=1.76. Similar models have been used to locate earthquakes in active volcanoes such as Redoubt (Lahr et al., 1994). So, this is the one used for the Citlaltepetl volcano.

Table II Earthquakes located using HYPOCENTER.

Attributes of Sismicidad_Pico

FID	Shape *	AÑO	MES	DIA	HORA	MIN	SEG	LAT	LONG	PROF	MAG	IM1	IM2	IM3	IM4	IM5	IM6
0	Point	1	6	25	0	36	56.34	19.05	-97.3	6.7	2.02	5	188	3	0	0	0
1	Point	1	7	4	20	16	55.91	19.04	-97.31	2.82	2.19	6	197	4	0	0	1
2	Point	1	7	4	22	18	25	19.04	-97.31	0	2.97	5	182	5	0	0	0
3	Point	1	8	1	11	33	40.55	19.13	-97.25	9.93	2.73	5	26	7	0	0	0
4	Point	2	7	14	2	3	57.31	19.05	-97.29	6.99	1.77	7	204	2	0	0	0
5	Point	2	10	20	18	10	17.6	19.1	-97.41	15.3	2.21	5	59	13	0	1	1
6	Point	2	11	3	14	54	23.11	19.06	-97.29	4.45	2.28	8	159	2	0	1	1
7	Point	2	11	6	10	11	53.93	19.06	-97.3	3.92	2.03	6	160	2	0	0	1
8	Point	3	12	28	19	17	35.35	19.11	-97.39	5.07	2.49	6	59	14	0	0	0
9	Point	3	12	29	6	18	54.18	19.03	-97.26	2.94	2.37	5	108	3	0	0	0
10	Point	4	1	1	1	26	32.06	19.07	-97.24	2.07	1.98	5	55	4	0	1	1
11	Point	4	1	4	18	7	40.6	19.01	-97.3	10.43	2.28	6	238	2	0	1	1
12	Point	4	2	9	13	0	16.7	19.02	-97.27	4.38	1.94	7	122	1	0	0	0

Record: 1 Show: All Selected Records (0 out of 13 Selected) Options

Figure 6 shows the plan map of the location of these events, AcGIS 9.2 and mapping of the INEGI of the state of Veracruz 1: 50,000 were used for its elaboration.

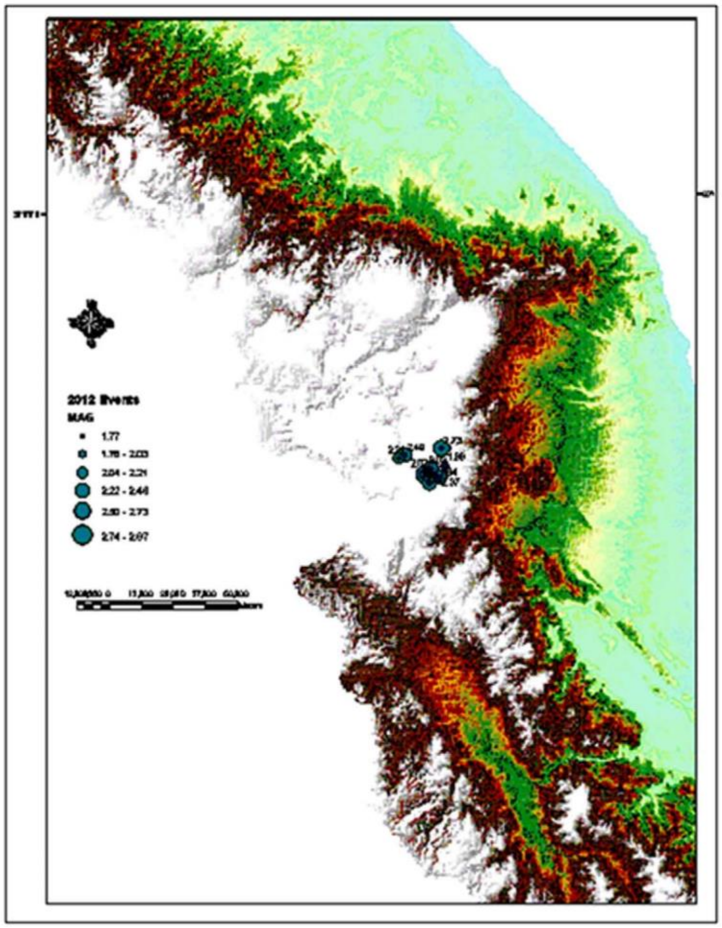


Figure 6. Location map of volcanotectonic earthquakes, the magnitudes of the earthquakes is Mc (magnitude of coda) vary in ranges from 1.77 to 2.97.

Since 2008, S.W.A.R.M (Seismic Wave Analysis Real-Time Monitor) software complementary to the Earthworm system has been used, which among other options allows to obtain a digital seismogram, where it is possible to visualize the earthquakes that are generated in the volcano. Once identified, the frequency spectrum and the spectrogram of the events recorded in the Citlaltépetl can be obtained, in figure 7 (a) and (b) a couple of examples of earthquakes recorded in 2012 are presented.

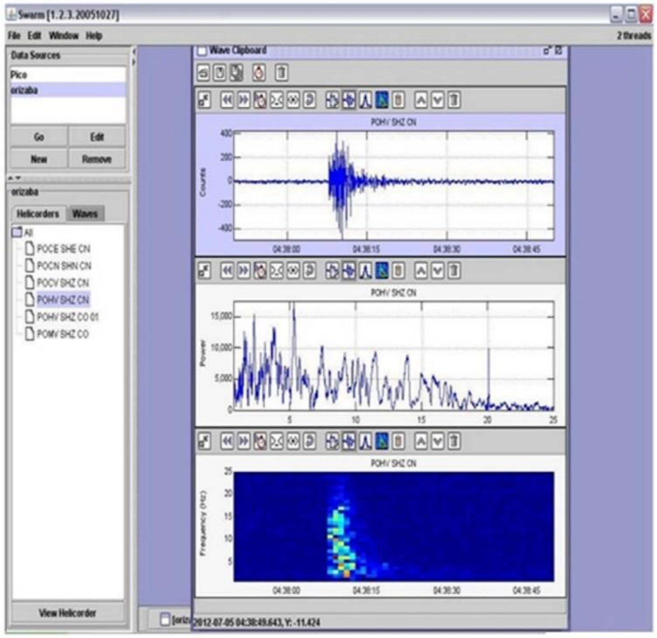


Figure 7 (a)

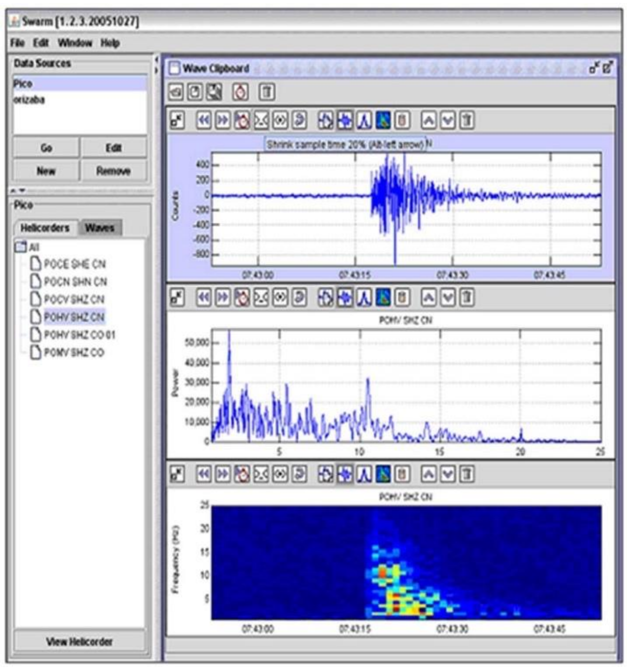


Figure 7 (b)

Figure 7 (a). Volcanotectonic earthquake recorded on July 5, 2012 at 04:38 (GMT) and in (b) Volcanotectonic on the same day July 5, 2012 at 07:43 (GMT).

Landslides

Landslides in volcanoes can be generated by dome collapses, explosions, occurrence of earthquakes, by dragging of unbound material that descends down the slopes of the slopes, etc. In the Citlaltépetl volcano, this type of event has been recorded mainly by the Chipe (POC) station, located in the south of the volcano, and its origin has been associated with the removal of small amounts of loose material on the slopes during the rainy season.

Regional Historic Seismicity

Another necessary aspect to know is the regional seismicity since they could have an influence on the Citlaltépetl volcano. In the state of Veracruz during the twentieth century important earthquakes occurred in this deep region (over 40 kilometers) and because they are located under the most populated area of Mexico (Mexican Volcanic Belt), they caused serious damage such as that of 1973 in the city of Orizaba Also in the entity there are also other types of earthquakes called cortical or shallow, which are very superficial intraplate events that occur within the North American plate (with depths between 5 and 35 kilometers) and whose magnitudes are considerably less than those of Subduction or deep earthquakes. An example of this is the Xalapa earthquake that occurred in 1920, which caused serious damage to this Veracruz city (Kostoglodov et al., 1999).

The Xalapa earthquake of January 3, 1920 (Ms = 6.2; Suter et al., 1996) ranks second nationally in number of victims with 650; Of these, 419 died from mudslides caused by the landslide of canyons. This earthquake originated in the Sierra Madre Oriental, between the states of Puebla and Veracruz, the epicenter being located 35 km southwest of the City of Xalapa (Suárez 1991, Flores and Camacho 1922). The third place corresponds to the Orizaba earthquake of August 28, 1973 (Mw 7.0; Singh and Wyss, 1976) with 539 deaths. Its epicenter was located in the state of Puebla very close to the border area with Veracruz at a distance of less than 40 km southwest of Orizaba.

In addition to the earthquakes of Xalapa and Orizaba, of great importance for the lives they claimed, there have been other earthquakes that damaged cities in the state such as the one in 1931 in Huajuapan de León, Oax., (Ms 7.8; Singh et al. 1985) that caused damage to the city Veracruz; that of 1937 (Ms 7.3; Jiménez and Ponce 1977-78) that affected the cities of Veracruz, Xalapa, Orizaba and Córdoba.

Therefore, the Center for Earth Sciences of the University of Veracruz with the advice of the SSN and the Department of Seismology of the Geophysics Institute of the UNAM proposed the installation of a seismic network for the state of Veracruz (Figure 8), through the projects: Atlas of Geological and Hydrometeorological Hazards of the State of Veracruz (Seismic Danger chapter) and the Seismological Network of the State of Veracruz for Seismic Risk Assessment. These projects were funded by the Natural Disaster Prevention Fund (FOPREDEN) and the Government of the State of Veracruz through the Secretary of Civil Protection.

Quantitative analysis of seismicity in the Citlaltepetl volcano

For the quantitative analysis of the seismicity of the Citlaltepetl volcano, graphs are produced that show the count of earthquakes recorded in the Citlaltepetl volcano from 1999 to June 2012 (figure 9) and another corresponding to the accumulated energy curve for the same period (figure 10). The seismicity review is carried out daily and therefore, the graphics are updated according to the earthquake register.

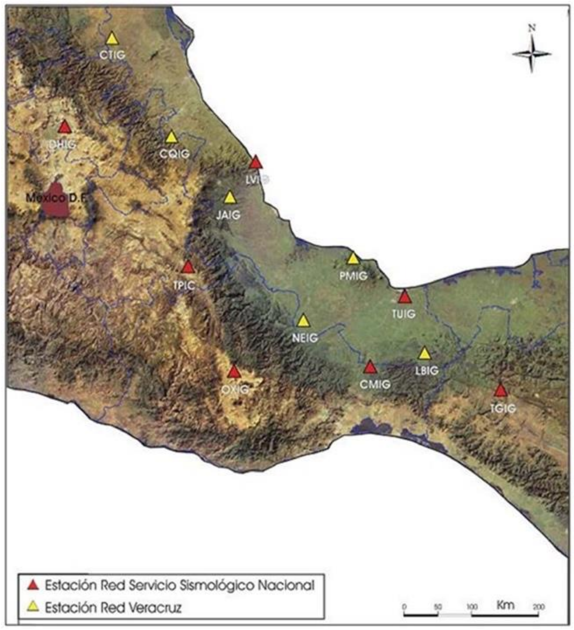


Figure 8. The seismic network for the state of Veracruz has 6 broadband and very broadband stations, with a distribution such that the best coverage is obtained in this region of the country and complemented by the equipment that the SSN already has in the entity (Laguna Verde and Tuzandepetl, LVIG and TUIG respectively) and those that are installed in the vicinity of the Veracruz territory that include the stations located in Hidalgo, Puebla, Oaxaca and Chiapas.

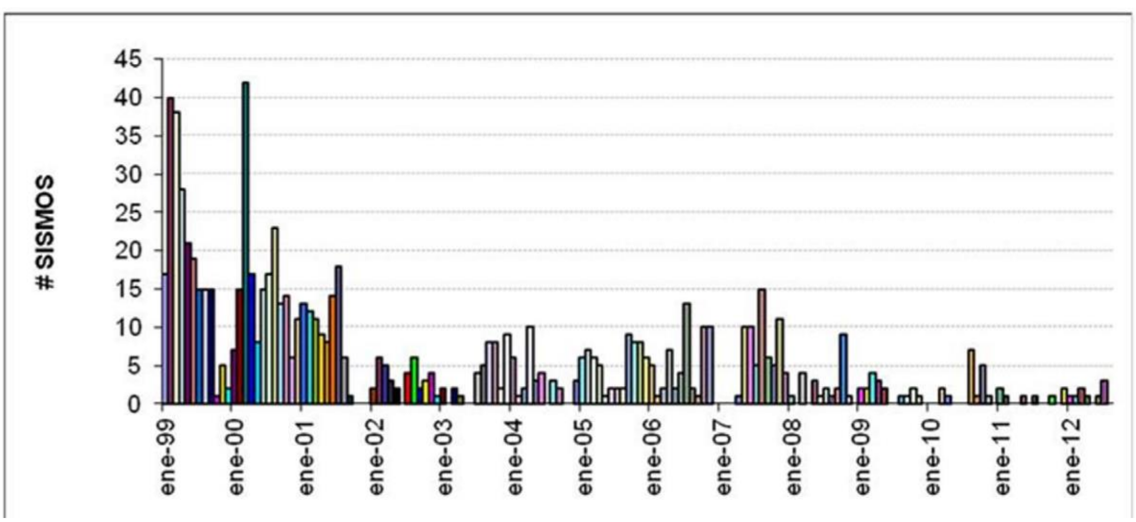


Figure 9. Volcanotectonic earthquake count for the Citlaltépetl volcano, the seismicity record covers from 1999 and considers until July 2012 (~ 12 years)

Figure 10. Graph showing the accumulated energy curve for the Citlaltepetl volcano. To date, about 871 earthquakes have been counted

Most likely scenarios in case of volcanic reactivation in the Citlaltépetl

In case of volcanic reactivation, the occurrence of any of the following manifestations is likely:

• Increase the level of local seismicity recorded by the stations located in the volcano, which the population could perceive generating fear.
• Light emissions of gas and / or ash that can affect livestock, cultivation areas, pollute water, affect roads, etc. In the houses they could cause roof collapses in precarious houses (sheet roofs) and generate acid rain, as well as health problems in the population.
• Presence of magma and incandescence in the crater.
• Formation of small domes and presence of small explosions that could destroy them, causing fragments of various diameters to fall around the volcano.

Conclusions

1. The seismic stations for the Citlaltepetl volcano, which have been operating since 1998 with the installation of the first station (POHV), have been managed to keep operating on a regular basis, however, it is necessary to make telemetric communication adjustments and make a modernization of the equipment and instruments.
2. Regarding the modernization of the seismic instrumentation, CENAPRED staff installed a broadband equipment (oral communication) in December 2011 (additional to the short period equipment) at the Chipe (POC) station, located on the southern flank of the volcano. The signal was received at the central registration post of CENAPRED, however, in mid-

2012, it stopped operating. CENAPRED staff is considering restoring its operation (personal communication) and sharing the signal with the CES in the near future.

3. On the other hand, in 2012 the staff of the CES of the UV in collaboration with personnel of the SSN of the UNAM, is carrying out activities related to the installation of broadband equipment in the POMV station, located in the east ring (W) of the volcano. The activities include remodeling the pedestal at the station, renewing the wiring and replacing the telemetric communication with a satellite communication system, the latter will be provided by the SSN.
4. Process, evaluate and classify the data generated by the seismic network allow to know the base seismic activity of the volcano. The type of earthquakes recorded in the volcano are volcanotectonics, present on, around and outside the building; their magnitudes Mc (magnitude of coda) vary in ranges from 1.77 to 2.97. Landslides are also recorded in the southern flank of the volcano. So far, the level of seismicity in the volcano remains stable.
5. Regarding the regional tectonic seismicity, a seismic installation for the state of Veracruz (6 stations) is being carried out through the projects: Atlas of Geological and Hydrometeorological Hazards of the State of Veracruz (Seismic Hazard chapter) and the Seismological Network of the State of Veracruz for Seismic Risk Assessment.
6. It is necessary to complement with other monitoring techniques (visual, geochemistry of springs, deformation, etc.) in order to establish correlations between various types of data. In this regard, the CES staff is taking steps to install a camera that provides a real-time image of the volcano that allows visible changes in the volcanic edifice. The site considered is the facilities of the Great Millimeter Telescope of the INAOE in Puebla, located in the southern flank of the volcano.

Recommendations

1. Derived from the geological history of the volcano, it is necessary to consider the scenario of the occurrence of an earthquake of great magnitude in the region that could cause collapse, landslides, avalanches, etc. Therefore, it is necessary that the Government and Civil Protection authorities contemplate this scenario and take the necessary measures.
2. It is suggested that the Civil Protection authorities carry out the development of instruments focused on the management of a volcanic emergency, using the Citlaltepetl volcano hazard map and the probable scenarios already mentioned, for example: developing an operational plan according to the possible scenarios mentioned, preparation of a map of primary and secondary routes in case of evacuation, selection in advance of sites for shelters, identification of the needs of the population subject to possible evacuations to be covered by the authorities, etc.

Acknowledgments

Special thanks to the staff of the Secretary of State Civil Protection of Veracruz for the support provided for the construction, installation and instrumentation of the seismic stations in the Citlaltepetl volcano.

References

Atlas of Geological and Hydrometeorological Hazards of the State of Veracruz. 2009. Gilbert Francisco Torres Morales, Ignacio Mora González, Francisco Córdoba Montiel. Seismic Hazard Chapter.

Burski M. 2008. A general model for tectonic control of magmatism: Examples from Long Valley Caldera (USA) and El Chichón (Mexico). International Geophysics 48 (1), pp. 171-183 (2009).

Calvin, E.M., Kudo, A.M., Brookins, D.G., Ward, D.B., 1989. Strontium isotope and trace element geochemistry of Pico de Orizaba-Trans-Mexican Volcanic Belt: comparison phases II and III, in, Continental magmatism; abstracts: New Mexico Bureau of Mines & Mineral Resources, Bulletin, pp. 131, 38.

Cantagrel, J.M., Gourgaud, A., Robin, C., 1984, Repetitive mixing events and Holocene pyroclastic activity at Pico de Orizaba and Popocatepetl, Mexico: Bulletin Volcanologique, 47, pp. 735-748.

Carrasco-Núñez, G., 1993, Structure-eruptive history and some major hazardous events at Citlaltepetl volcano (Pico de Orizaba), Mexico: Hoghton, U.S.A., Michigan Technological University, Doctoral thesis, 182 pp.

_____-Núñez, G., 1997, Lava flow growth inferred from morphometric parameters–a case study Citlatepetl volcano: Geological Magazine, 134, pp. 151-162.

_____-Núñez, G., 1999, Holocene block-and-ash flows from summit dome activity of Citlaltepetl volcano, eastern México: Journal of Volcanology and Geothermal Research, 88, pp. 47-66.

_____-Núñez, G., Ban, M., 1994, Geologic map and structure sections of the summit area of Citlaltepetl volcano, México with summary of the geology of the Citlaltepetl volcano summit area: México D.F., Universidad Nacional Autónoma de México, Instituto de Geología, Cartas Geológicas y Mineras, 9, 1 mapa, texto explicativo.

_____-Núñez, G., Rose, W.I., 1995, Eruption of a major Holocene pyroclastic flow at Citlaltepetl volcano (Pico de Orizaba), México, 8.5-9.0 ka: Journal of Volcanology and Geothermal Research, 69, pp. 197-215.

_____-Nuñez, G., 2000, Structure and proximal stratigraphy of Citlaltépetl volcano (Pico de Orizaba), México, en: Delgado- Granados, H., Aguirre-Díaz, G., Stock, J.M., (eds.), Cenozoic volcanism and tectonics of México: Boulder, Colorado, Geological Society of America Special Paper, 334, pp. 247-262.

De-la Cruz-Reyna, S., Carrasco-Nuñez, G., 2002, Probabilistic hazard analysis of Citlaltépetl (Pico de Orizaba) Volcano, eastern Mexican Volcanic Belt: Journal of Volcanology and Geothermal Research, 113, pp. 307-318.

Díaz-Castellón, R., 2003, Analysis of the stability of volcanic buildings on the eastern flank of the Sierra de Citlaltépetl-Cofre de Perote. D.F., National Autonomous University of Mexico, Institute of Geology, Postgraduate Program in Earth Sciences, Master's Thesis, 135 pp.

Espíndola J.M, Zamora-Camacho A., Godinez M.L., Schaaf P., Rodríguez S.R. 2010. The 1793 eruption of San Martín Tuxtla volcano, Veracruz, Mexico. Journal of Volcanology and Geothermal Research 197, pp 188–208.

Flores T., H. Camacho. (1922). "Mexican Earthquake of January 3, 1920", Bulletin 38, Mexican Geological Institute. http://bcct.unam.mx/bogeolpdf/geo38/.

Gómez-Tuena, A., Carrasco-Núñez, G., 1999, Fragmentation, transport and deposition of a low-grade ignimbrite: the Citlaltépetl ignimbrite, eastern Mexico: Bulletin of Volcanology, 60 (6), pp. 448-464.
Basic Guide for the Development of State and Municipal Atlases of Hazards and Risks. Geological Risks Development of Volcanic Hazard Maps. 2006. Martínez A., Gómez A., De la Cruz S. CENAPRED. Secretary of the Interior.
Hidayat, D., Voight, B., Langston, C., Ratdomopurbo, A., y Ebeling, C. 2000.Broadband seismic experiment at Merapi volcano, Java, Indonesia: very-longperiod pulses embedded in multiphase eathquakes. J. Volcanol. Geotherm. Res. 100, pp. 215-231.
Hoskuldsson, A., 1992, Le complexe volcanique Pico de Orizaba- Sierra Negra-Cerro Las Cumbres (sud- est mexicain): structure, dynamismes eruptifs et evaluations del areas: Clermont-Ferrand, Francia, Université Blaise Pascal, Tesis doctoral, 210 pp.
Hoskuldsson, A., Robin, C., Cantagrel, J.M., 1990, Repetitive debris avalanche events at Volcano Pico de Orizaba, México, and their implications for future hazard zones, en: IAVCEI International Volcanological Congress, Mainz, Germany, Resumen, 47.
_____, A., Robin, C., 1993, Late Pleistocene to Holocene eruptive activity of Pico de Orizaba, eastern México: Bulletin of Volcanology, 55, pp. 571-587.
Ibáñez, J. M., Carmona E., 2000. Volcanic seismicity. Edition of House of the Volcanoes.
_____, J. M., Morales J., Alguacil, G., Almendros, J., Ortíz R., Del Pezzo, E. 1997. Intermediate-focus earthquakes under South Shetlands Islands (Antarctica). Geophys. Res.Lett.,24: pp. 531-534.
Iverson, R.M., Schilling, S.P., Vallance, J.W., 1998, Objective delineation of lahar inundation hazard zones: Geological Society of America Bulletin, 110, pp. 972-984.
Jiménez, Z and L Ponce (1977-78), "Focal mechanism of six large earthquakes in northern Oaxaca, México, for the period 1928-1973", Geof. Int. Vol. 17, pp. 379-386.
Kostoglodov, V., Pacheco J.F. 1999. Cien años de sismicidad. Instituto de Geofísica. UNAM. Poster.
Kover, T., 1995, Application of a digital terrain model for the modelling of volcanic flows: a tool for volcanic hazard determination: Buffalo, State University of New York at Buffalo, Master's Thesis, 62 pp.
Kudo, A.M., Jackson, M.E., Husler, J.M., 1985, Phase chemistry of recent andesite, dacite, and rhyodacite of volcan Pico de Orizaba, Mexican Volcanic Belt: evidence for xenolithic contamination: Geofísica Internacional, 24, pp. 679-689.
Lahr, J. C; Chouet, B.A; Stephens, C. D; Power, J. A. and Page, R. A. 1994. Earthquake classi cation, location and error analysis in volcanic environment: implications for the magmatic system of the 1989-1990 eruptions at Redoubt Volcano, Alaska. Journal of Volcanology and Geothermal Research, vol. 62, no. 1-4, pp 137-152.
Lee, W. K. H. y J. Lahr., 1975 A computer program for determining hypocenter, magnitude, and first motion pattern of local earthquakes, U. S. G. S. Open le Report, pp. 75-311.
Lienert, B. R. E., E. Berg, and L. N. Frazer, 1986. HYPOCENTER, An earthquake location method using centered, scaled, and adaptively damped least squares, Bull. Seis. Soc. Am. 76, pp. 771-783.
Macías J. L. 2005. Geology and eruptive history of some of the great active volcanoes of Mexico. Bulletin of the Mexican Geological Society Centennial Commemorative Volume Selected Topics of Mexican Geology Volume LVII, no. 3, 2005, pp. 379-424.

Malone S.D., Endo E. T., Weaver C. S., Ramey J. W. 1981. Seismic monitoring for eruption prediction. En: The 1980 Eruptions of Mount St. Helens, Editado por Washington, P. W. Lipman y D. R. Mullineneaux. USGS, Prof.Pap. 1250, pp. 803- 813.

_____, S.D., Boyko, C., y Weaver, C.S. (1983) Seismic precursors to the Mount St. Helens eruptions in 1981 and 1982.Science.221, pp.1376-1378.

Mooser, F., Meyer-Abich, H., McBirney, A. R.,, 1958, Catalogue of the active volcanoes of the world including solftara elds. Part VI Central America: Napoli International Volcanology Asociation, pp. 1-36.

Negendank, J.F.W., Emmerman, R., Krawczyc, R., Mooser, F., Tobschall, H., Werle, D., 1985, Geological and geochemical investigations on the eastern Trans-Mexican Volcanic Belt: Geo sica Internacional, 24, pp. 477-575.

Newhall, C.G., Self, S., 1982. The Volcanic Explosivity Index (VEI): An estimation of explositivy magnitude for historical volcanism. J. Geophys. Res. 87C2, 1231-1238.

Okada H., Watanable H., Yamashita H. y Yokohama I.1981. Seismological signi cance of the 1977-1978 eruptions and the magma intrusion process of Usu Volcano, Hokkaido.J. Volcanol. Geotherm. Res. 9, pp. 311-334.

Robin, C., Cantagrel, J.M., 1982, Le Pico de Orizaba (Mexique):structure et evolution d'un gran andésitique complexe: Bulletin of Volcanology, 45, pp. 299-315.

Rossotti, A., Carrasco-Núñez, G., 2004, Stratigraphy of the 8.5–9.0 ka B.P. Citlaltépetl pumice fallout sequence: Revista Mexicana de Ciencias Geológicas, 21(3),pp. 353-370.

Sheridan, MF, Carrasco-Nuñez, G., Hubbard, BE, Siebe, C., Rodríguez- Elizarrarás, S., 2002, Map of dangers of the Citlaltépetl Volcano (Orizaba Peak), scale 1:25 000: National Autonomous University of Mexico, Institute of Geology, 1 map.

_____, M.F., Hubbard, B., Carrasco-Núñez, G., Siebe, C., 2004, Pyroclastic ow hazard at Volcán Citlaltépetl: Natural Hazards, 33, pp. 209-221.

Siebe, H.C., Abrams, M., Sheridan, M., 1993, Major Holocene block-and ash fan at the western slope of ice-capped Pico de Orizaba volcano, México: implications for future hazards: Journal of Volcanology and Geothermal Research, 59, pp. 1-33.

Singer, B.S., Kudo, A.M., 1986, Origin of andesites and dacites from Pico de Orizaba, Mexican Volcanic Belt: Sr isotope and phase chemistry: Geological Society of America, Abstracts with Programs, 18(2), 186 pp.

Singh, S. K., and M. Wyss (1976).Source parameters of the Orizaba earthquake of August 28, 1973, Geo s. Int.16, pp. 165–184.

_____, S. K, G Suárez and T Domínguez.1985. "The great Oaxaca earthquake of 15 January 1931: Lithosphere normal faulting in the subducted Cocos plate", Nature, Vol. 317, pp. 56-58.

Suárez, G. (1991). "The earthquake of Xalapa of January 3, 1920", Journal of Seismic Engineering, SMIS, # 42, Mexico D.F

Suter, M, M Carrillo-Martínez and O Quintero-Legorreta (1996), "Macroseismic study of shallow earthquakes in the central and eastern parts of the Trans-Mexican Volcanic Belt, México", Bull. Seism. Soc. Am, Vol. 86, pp.1952-1963.

Tilling I. R. (1989). Volcanic hazards. Notes for a short course. World Organization of Volcano Observatory.WOVO.

Verma, S.P., 2006. Extension related origin of magmas from a garnet-bearing source in Los Tuxtlas volcanic eld, Mexico. Int. J. Earth Sci. 95, pp. 871–901.

Waitz, P., 1910-1911, Geological observations about the Pico de Orizaba: Bulletin of the Mexican Geological Society, 7, pp. 67-76.
Yáñez-García C., García-Durán, S., 1982, Exploration of the Los Humeros-Las Derrumbadas geothermal region, states of Puebla and Veracruz: Mexico, Federal Electricity Commission, Technical Report, 96 pp.
Zimbelman, D., Watters, R., Firth, I., Breit, G., Carrasco-Núñez, G., 2004, Stratovolcano stability assessment methods and results from Citlaltépetl, Mexico: Bulletin of Volcanology, 66, pp. 66-79.

Chapter 5

Mass movement processes in the San Andrés Tuxtla region, Veracruz

Katrin Sieron

Abstract

Every year, several communities of San Andrés Tuxtla and Santiago Tuxtla municipalities are affected by small to medium scale mass movement processes, first and foremost slides and falls during the rainy season or in some cases weeks after the season ending.

The climate conditions in Los Tuxtlas, together with soil characteristics, local geology (easily erodible basin sediments), abrupt topographical changes and a growing human intervention cause an annual increase of mass movement phenomena incidents in the region.

The most affected areas are located within the contact zone of Tertiary sediments of the Veracruz basin to the south and the volcanic Los Tuxtlas massif to the north. The contact zone between the two geologic complexes is characterized by pronounced scarps along fault systems. To be able to determine the slope susceptibility for experiencing landslides, the Mora-Vahrson method was used, employing 5 values of which 3 are intrinsic (lithology Si, soil humidity Sh and relative relief Sr) and two are triggers (seismic activity Ts and Precipitation Tp).

The landslide hazard maps were elaborated in a Geographic Information System (GIS) applying the formula $H = (Si*Sh*Sr)*(Ts+Tp)$ to determine susceptibility H.

The resulting maps indicate the areas with more or less susceptibility for experiencing landslide phenomena during different scenarios.

The results were compared with field observations to be able to verify the efficiency of the method used.

Introduction

San Andrés Tuxtla is the head of a municipality of the same name in the state of Veracruz. It is located in the Los Tuxtlas area, which is located south of the state of Veracruz on the coast of the Gulf of Mexico (Figure 1). Apart from San Andrés Tuxtla, Santiago Tuxtla and Catemaco are other important population centers. The region of Los Tuxtlas is of volcanic origin with the three volcanoes San Martín Tuxtla, Santa Marta and San Martín Pajapan and hundreds of monogenetic volcanic buildings. The volcanic massif rises over the Veracruz Basin.

Mass movement processes have increasingly affected localities in the municipalities of San Andrés Tuxtla and Santiago Tuxtla, which creates the need to better understand the problem to avoid material and human damage in the future. In addition, its application will allow the establishment of planning guidelines.

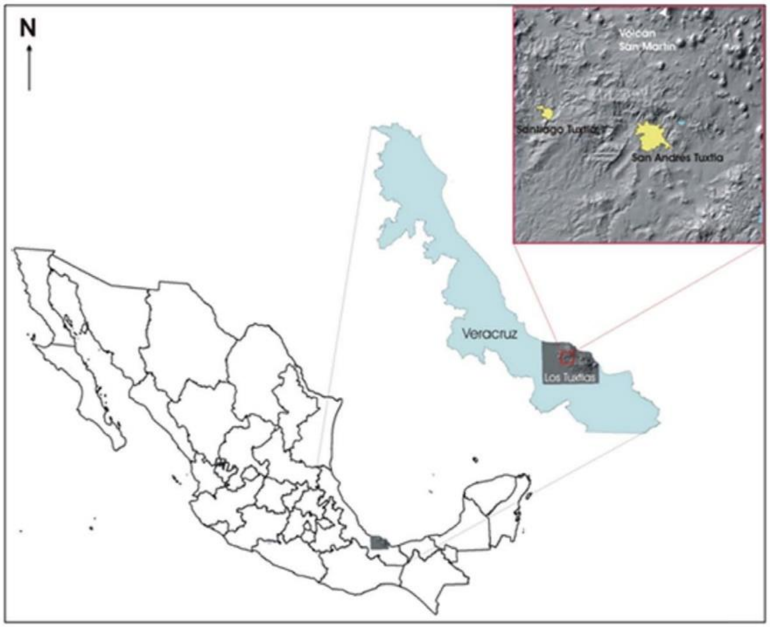


Figure 1. Location of Los Tuxtlas and the study area.

Mass movement phenomena are processes of mobilization and transport of material (rock, soil, etc.) slowly or quickly, caused by a series of factors and controlled mainly by gravity (Cruden, 1991).Mass movements have been classified in different ways by a number of authors (eg Sharpe, (1939); Nemcok et al. (1972); Varnes (1978); Cruden and Varnes (1996); the latter presented a classification that mass movement phenomena fall into the following categories:

- Detachments (or Falls)
- Landslides (rotational and translational)
- Flows
- Overturnings (or Topplings)
- Side extensions

The types of movements are presented in Table I and an image of them is shown in Figure 2.
To classify a specific case of a mass movement phenomenon, different factors that alone or in combination are causing the process are taken into account:

- Lithological factors (such as overlapping rocks / unbound material on consolidated rocks)
- Structural factors (physical, chemical, biological weathering of the surface layer)
- Topographic factors (such as slopes with steep slopes)
- Anthropic factors (denudation or deforestation of the land)
- Tectonic factors (such as the occurrence of earthquakes)
- Climate factors (heavy or continuous rainfall

The factors can be divided into two large groups: the conditioning factors and the triggers.

The triggers can be divided between the natural ones, such as earthquakes, heavy rainfall, undermining and river erosion or volcanic eruptions and induced or anthropic eruptions, such as the increase in slope weight (due to accumulation of buildings for example), excavation with withdrawal of materials of the foot of the slope or slope, creation of artificial slopes or explosions made to mention some.

Table I. Types of mass movements; modified after Varnes (1978).

Type of Movement		Type of Material		
		Rock	Scree	Soil
			Coarse grain	Fine grain
Falls / Detachments		Rock fall or detachment	Fall or dislodgement of debris	Fall or loosening of soil
Crashes/Topplings		Rock crashes or rollovers	Debris crashes or rollovers	Toppling / landslide
Slides	Rotational	Rock sliding	Scree sliding	Landslides
	Translational			
Lateral spreads		Lateral rock spreads	Lateral scree spreads	Lateral soil spreads
Flows		Rock flow	Detritus flow	Soil flow
Complex		Combination of two or more types of movements		

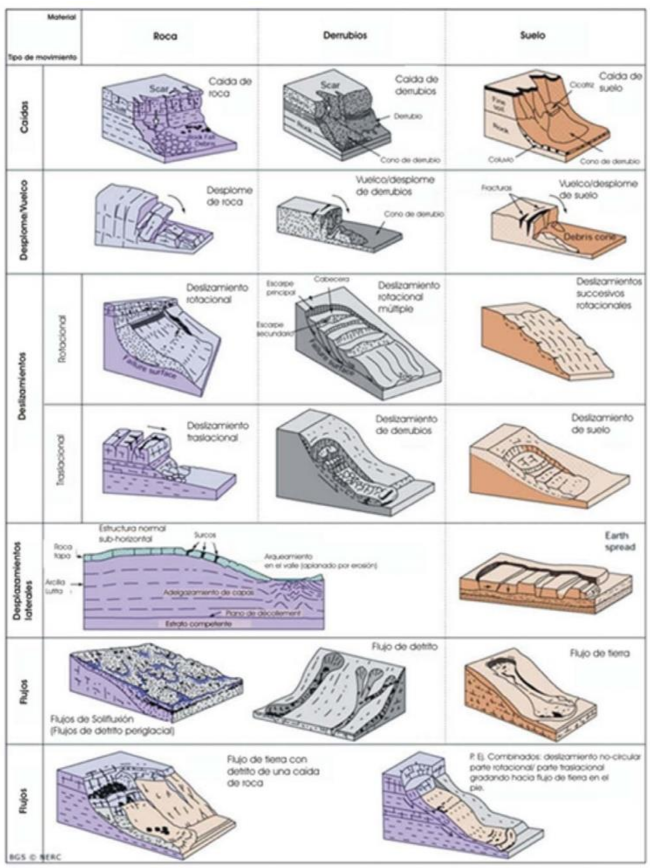


Figure 2. Images of the types of mass movements presented in Table I (source: British Geological Survey, BGS)

Description of the study area

Morphological / topographic characteristics

The area of Los Tuxtlas is characterized by a complex morphology with variable slopes (Figure 3A). In the area to the north and west of San Andrés Tuxtla there is a contact between two geological units (Tertiary sediments of the Veracruz Basin and La Tuxtlas Volcanic Massif lavas) which is topographically marked by a steep escarpment with slopes up to 74 ° (Figure 3B). This escarpment is associated with a fault system (eg Andreani et al., 2008).

Tertiary sediments (see geological features) found in these high-slope areas, such as north and west of San Andrés Tuxtla, around Santiago, as well as west of Lake Catemaco, are more likely to experience phenomena of mass movement such as landslides and landslides.

Geological features

In the study area there are two geological provinces: the Los Tuxtlas Volcanic Massif, and the Veracruz Basin. While the Volcanic Massif is composed of volcanic rocks such as lavas of predominantly basaltic compositions and pyroclastic deposits of different nature, the Veracruz Basin is mainly composed of Tertiary sediments (such as sandstones, shales, etc.). The contact between both units is expressed through escarpments and a fault system.

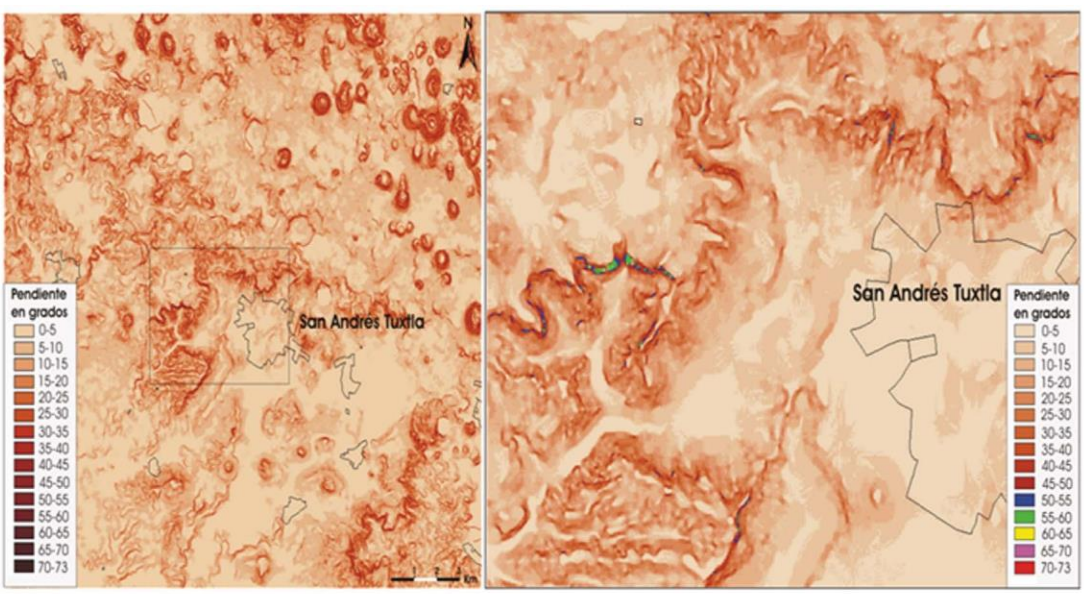


Figure 3. (A) Slopes of the study area. Darker colors indicate steeper slopes. (B) approach to the west area of San Andrés; slopes> 50 ° were highlighted using colored dots.

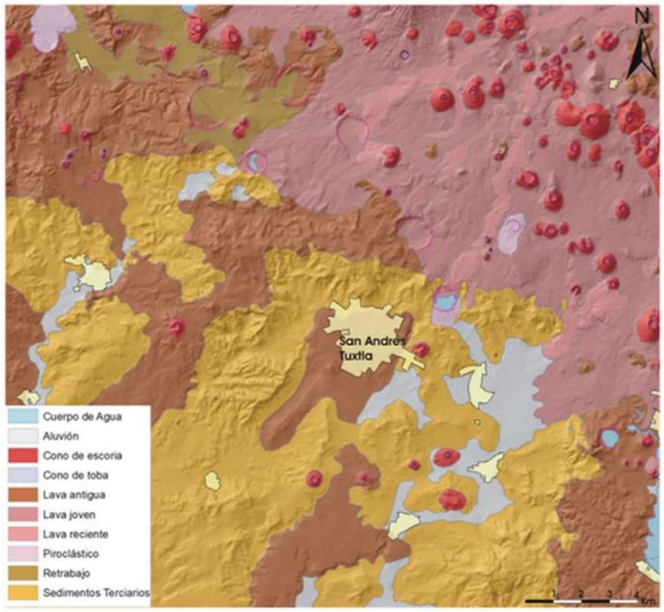


Figure 4. Geological map of the study area. (Yellow color: sediments of the Veracruz Basin, brown to purple colors: volcanic sequences of different ages; red color: cinder cones, pink lines: explosion craters (maars); gray: alluvium).

Climatic characteristics

The climate in the Los Tuxtlas region varies between tropical and humid subtropical, due to the altitudinal range. Data collected at the Tropical Biological Station of "Los Tuxtlas" show an annual rainfall of more than 4500 mm (Guevara Sada et al., 2000). Although rainfall occurs throughout the year, most of them are expected in the months of June to February.

The climatic conditions favor intense weathering, erosion and alteration of the rocks and sediments of the region, which in turn contributes to the conditioning factors for the production of a mass movement (eg Terzaghi, 1950; Varnes, 1978).

Methodology for the identification of susceptible areas to present mass movement in the San Andrés Tuxtla region

Among the mass movement processes, described in Table I, in the study area were observed:

- Different types of flows (detritus, soil, lahars flow)
- Detachment / fall /toppling of rock

In the surroundings of San Andrés Tuxtla, flows (detritus flow, soil flow) can be observed on the flanks of cinder cones (Figures 5A and 5B), landslides (Figure 5C), slow flow or creep (Figure 5D), landslides and toppling (Figure 5E), as well as lahars (mud flows down the volcano's anchors) (Figure 5F).

To determine the areas susceptible to presenting the phenomenon of mass movements, a methodology that considers lithological, topographic, tectonic and climatic factors was applied (Mora and Vahrson, 1994). Using the geographic information systems (GIS) as a tool, 3 maps of conditioning factors (geology = Si factor, soil moisture = Sh factor and slope = Sr factor) and 2 triggers (strong rainfall = Tpy factor earthquakes =) are prepared Ts factor).

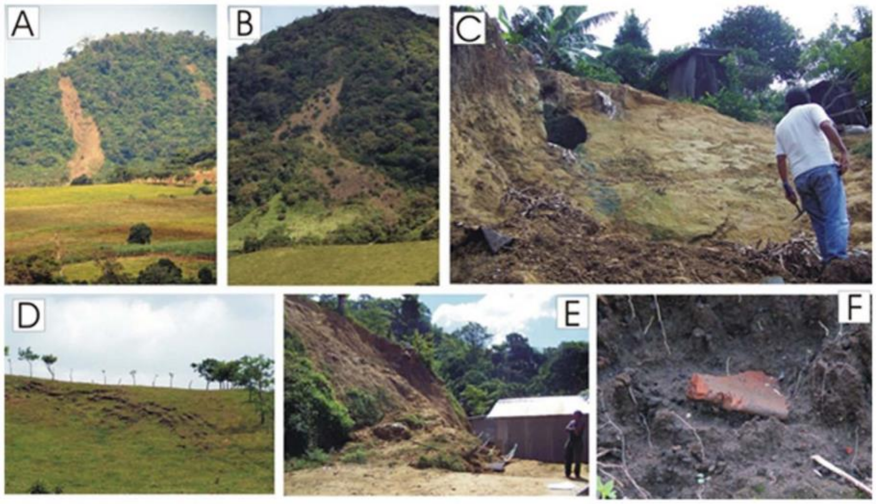


Figure 5. Variety of mass movement phenomena in Los Tuxtlas, near San Andrés (Photos: K. Sieron).

These 5 maps are combined, using a formula in the "raster calculator" of the GIS (susceptibility H= (Si*Sh*Sr)*(Ts + Tp)), in order to obtain final maps that can be interpreted to assign low zones at high susceptibility by mass movement.

Results

Three maps are produced using the three combinations of triggers (Earthquake, Rain, and Earthquake and Rain) (Figures 6A - 6C).

The areas that have the highest susceptibility (in this case medium susceptibility) are for example: cinder cones with high slopes and the areas north and west of the San Andrés Tuxtla municipal head where there are high slopes and sediments of the Veracruz basin.

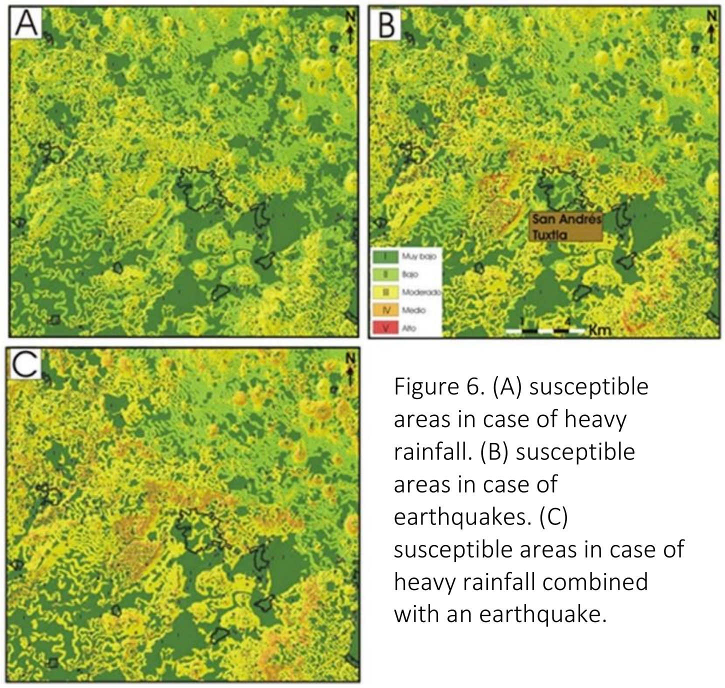


Figure 6. (A) susceptible areas in case of heavy rainfall. (B) susceptible areas in case of earthquakes. (C) susceptible areas in case of heavy rainfall combined with an earthquake.

In several communities near San Andrés Tuxtla that are located just above the areas of greatest susceptibility, landslides are observed annually (as are other types of mass movements) (Figure 7).

Figure 7. Examples of homes that are located in areas with a medium susceptibility to experiencing PRM in the towns north of San Andrés Tuxtla (Texcaltitán and Tonalapan). Photos taken in 2010 by K. Sieron.

Discussion

The susceptibility of a region to the phenomenon of mass removal depends on where it is located, the type of human activity in the region, the use of the soil and the frequency of the occurrence of the phenomenon. Damage caused by mass removal can be prevented by applying methodologies such as the one presented in this work to produce susceptibility and danger maps that indicate the most prone areas. With the information on these maps, better urban planning can be done, as well as making recommendations to the Government and Civil Protection authorities to take prevention measures (relocation to safer areas, application of measures for the stabilization of dangerous slopes, reforestation , redirection of surface waters, etc.) and carry out the application of measures during the rainy season (temporary evacuations of houses, etc.).

Conclusions

The method applied to determine the areas prone to undergo mass removal processes in this work - Mora-Vahrson method - uses relatively easy parameters to obtain and produces susceptibility maps integrated into a GIS. The results obtained through this method offer an overview of areas susceptible to the phenomenon. The observations made in the field indicate coincidences between the most susceptible areas (determined with the method) and traces of past removal processes. For a more detailed study of a particular hillside this method is not the most appropriate.

Acknowledgments

This study was carried out thanks to the support of FOPREDEN funds and the Government of the state of Veracruz through the Secretary of Civil Protection of the state within the framework of the project "Geological Study of the San Martin Tuxtla volcano, Veracruz. Equipment, Instrumentation and Monitoring for disaster prevention purposes."

References

Andreani L., Rangin C., Martínez – Reyes J., Le Roy C., Aranda – García M., Le Pichon X., Peterson-Rodriguez R., 2008, The Neogene Veracruz Fault: evidences for left-lateral slip along the Southern Mexico Block. Bulletin of the Société Géologique de France, T. 179 (2), pp. 195-208.
CRUDEN, D.M. 1991. A simple definition of a landslide, IAEG Bull ..43, pp. 27-29.
_____, D.M., Varnes, D.J. 1996. Landslide types and processes. In: Turner A.K .; Shuster R.L. (eds) Landslides: Investigation and Mitigation. Transp Res Board, Spec Rep 247, pp. 36–75.
Guevara Sada, S., Laborde Dovalí, J., Sánchez-Ríos, G. 2000. The Los Tuxtlas Biosphere Reserve - Working documents. 29, pp. 1-50.
Nemčok, A., Pašek, J. and Rybář, J. 1972. Classification of Landslides and Other Mass Movements. Rock Mechanics 4, pp. 71-78.
Mora, S., Vahrson, W.G. 1994. Macroeconomic methodology for landslide hazard determination. Bull. Engin Association Geol., 31, 1, pp. 49-58.
British Geological Survey, BGS, www.bgs.ac.uk

Sharpe, C.F.S. 1939. Landslides and Related Phenomena. Cooper Square Pub, Inc., New York, 137 pp. Terzaghi, K. (1950). Mechanisms of Landslides. Geol. Soc. Am. Bull., Berkeley, pp. 83-123.
Varnes, D.J. 1978. Slope Movement types and Processes. In: Landslides, Analysis, and Control (Shuster, R.L. and R.J. Kriszek, Eds.) National Academy of Science, National Research Council Transportation Research Board, Washington D.C. pp. 11-33.

Chapter 6

Integral management of watersheds from a complex systems approach

María del Socorro Menchaca Dávila
Javier Bello Pineda

Abstract

Management Methodology for Integrated Watershed (GEMIC), aims to investigate the basins under the complex systems approach, set in the context of sustainable development. This methodological tool seeks to develop knowledge building processes in interdisciplinary areas of environmental, social and economic, to propose policies and strategies are built on the production of scientific knowledge.

Presentation

The GEMIC is a methodological instrument that was developed in the context of the Water Observatory for the State of Veracruz, OABCC (Water, Forests, Basins and Coasts), a scientific model that is a university initiative promoted by professors / researchers belonging to different academic entities and regions of the University of Veracruz. The OABCC aims to develop knowledge in the context of comprehensive watershed management and management, so that public policies and efficient strategies are formulated in a timely manner that consider human impacts on the environmental health of current and future watersheds.

The methodology is aimed at proposing public policies and strategies aimed at solving problems related to the natural and anthropogenic water cycle in watersheds, as well as determining trends and scenarios from a scientific perspective and doing so, addressing it from the approach of complex systems. The general context of the GEMIC strategy is based on the so-called sustainable development that describes an ecologically enduring and socially just socio-economic process.

The general sense pursued by sustainable development is closely related to the following aspects: the satisfaction of basic needs for all human beings in the present and the future; the preservation of biodiversity and ecosystems; the decrease in energy consumption and the development of technologies from renewable sources, ecologically healthy economic growth, among others.

Under this approach, the basin is defined as the limited space that includes from the aspects that cover the geological forms of the land that capture, concentrate and distribute the different water flows that come from the region's rainfall, to the aspects related to the ecosystems , the human beings that inhabit spaces and territories, as well as those related to the economy in terms of systems and modes of production of goods and services.

In the GEMIC methodology, a series of large stages are established, which are related to each other in a sequential development process (see figure 1). However, it is pointed out that the core attribute of the methodology is the exibility, this means that, within each of the stages or phases, the order and seriation of the actions that are established are not schematically obeyed, that is, the methodological development is not linear, on the contrary, the process adapts to the requirements set by the course of research on the complex basin system (s). The above allows to develop feedback processes that allow changes and adjustments to achieve a scientific work of the highest quality. Below are the stages of methodological development, which are explained in the sections that make up the GEMIC.

Construction of the systematic vision of basins

This first stage involves the construction of the vision of a complex system, which can cover a basin or several, which is established as an object of study and / or intervention. It should be noted that this work is itself of a subjective nature, because it is not possible to have the multiplicity of information to have a total view of the object of study and / or intervention.

The systemic approach is the key and starting point to homogenize the vision of the system, which means recognizing that the governance for the integral management of a basin implies influencing complex problems (or complex situations), which are determined by the confluence of multiple factors that interact and can be interdependent, in such a way that it is not possible to isolate, describe or explain them "adding" partial studies carried out independently by different specialists.

The rationale for the above is that different aspects of the physical - biological environment, social organization, economy, production, technology, anthropogenic factors and their relationship with environmental services, etc. are involved in the phenomena that occur in the basins. ., which in turn implies the confluence of multiple processes (in which various fields of knowledge can intervene), whose interrelationships constitute the structure of the system that functions as an organized totality, and is what is defined as a complex system.

It should be noted that this analysis approach, in which the GEMIC is approached from the perspective of complex systems, derives from the fact that it is not possible to have certainty about the magnitude and quality of the phenomena, however, one must act with the system that is the object of study in which it is decided to investigate, work and / or intervene.

The above is the basis that supports the definition, determination and / or delimitation of the object of study that includes the following aspects:

- The definition of the initial questions
- The context determination of the object of study
- The establishment of the conceptual framework

The definition of the initial questions

These will serve to define the categories that make up the system in the case of watersheds, which are three: environmental, social, and economic and their elements, understood as the disciplines that cover them; and in parallel, establish an approach to the interrelationships between disciplines and / or fields of knowledge of the complex system / object of study that are the basins.

The above is a guide for the understanding of the research / intervention processes since, on the one hand, the initial explanatory scheme is established, on the operation of a system characterized by phenomena that are determined by processes where the System categories, and on the other, the fields of knowledge and / or disciplines that intervene in each of the categories of the basin system (s) are defined. In this case, the initial questions of the GEMIC are the following:

What is the behavior of the natural and anthropogenic water cycle in the study and / or intervention basins? And what are the management strategies for the integral management of watersheds, from the perspective of the so-called sustainable development?

It should be noted that, the establishment of the interdisciplinary approach is the basis for developing all phases of research and also that the development of this approach starts from the formulation of the vision of the object of study and the formulation of the initial questions that will guide the process that It is not linear, since it goes through different phases, each with different forms of group organization or specific procedures that must be established among all the members of the working group.

The context determination of the object of study

This implies necessarily making a “cut” of reality, without affecting, fragmenting and / or segmenting the physical-biological context for the analysis and / or study of a basin. This determination is an abstraction that is useful to specify the geographical space that is established for different purposes: delimit it, characterize it, understand its magnitude in general terms, this according to the type of basins that you want to investigate and / or intervene, between other aspects

A fundamental aspect to investigate and intervene in a complex system is to establish its dimensions. According to Fenzl (2010, p. 9) "... the definition of a complex system relates the internal space and the external space of the system, by including an intermediate mesoscopic dimension (from the Greek meso-entre)." author distinguishes three basic dimensions of space time in complex systems that act in synergy:

The microscopic one, which describes the internal space at the level of the individual parts (the elements of the system), which are related in a non-linear way.

The mesoscopic, which is the structural boundary of the system that separates the interior space (space of the interactions between the elements) and the outer space of the system structure.

The macroscopic, formed by space beyond the structural border, also called the field of interaction. This part external to the structural frontier is the source of energy and matter for the maintenance of the metabolism of the system called basin.

In a practical way, the determination of the breadth of the object of study, derives in the elaboration of the map of the basin (s) where it has been decided to investigate and intervene, by means of the cartographic representation, the territorial limits and the localities included within the geographical area.

Establishment of the conceptual framework

The requirement that represents the research or study related to the area of management for the integral management of basins, where the operation of a complex system is at stake, can be developed through a work team that builds epistemic, conceptual and methodological frameworks that are defined jointly, that its scope and depth be shared and understood among all group members.

The conceptual framework implies the theoretical baggage constituted from the perspective of the different fields of knowledge / disciplines and / or researchers, and how they identify, select and organize them. Because the use of concepts, terms, definitions and references in the management and integral management of basins is diverse and complicated, it is important to establish processes that allow consensus.

Regarding the conceptual framework, in the GEMIC, for example, the concept of basin was defined, with the participation of the multidisciplinary group of the Water Observatory for the State of Veracruz, OABCC (Water, Forests, Basins and Coasts), which is established at the beginning of the chapter.

From this definition, a series of central concepts emerge that should be analyzed in greater detail such as: the type of basin, state and trends in terms of basic factors such as water availability; water quality; aspects about society, economy and institutions related to watershed management and integral management; Resilience, strategies and sustainability parameters, among others, which are defined and shared by the work team.

Build and address together, among all fields of knowledge or disciplines, aspects related to the determination of the systemic vision of a basin, implies the understanding of the underlying complexity in it, and also have the necessary tools for its governance and comprehensive management.

Information System of the Observatory of Water, Forests, Basins and Coasts.

The development of the GEMIC is based on the Information System of the Observatory of Water, Forests, Basins and Coasts (SIOABCC), which is constituted by a series of sections integrated into databases or theoretical - conceptual and methodological information, which are useful and / or necessary to diagnose, monitor and detect complex problems, within the framework of management for the integral management of watersheds. These sections, in general terms, relate to the categories of the basin system (s) of the social, economic and environmental aspects and cover the natural and anthropogenic hydrological cycle, issues that allow identifying the conditions in which the basin is located and its “health".

The four phases of said cycle are the following:

- Resource availability related to sources of supply in terms of quantity and quality;
- Distribution of the hydraulic system and / or distribution networks;
- Use of the resource that integrates the supply and demand of water users, rational use and overexploitation;
- Management related to eviction, sewage treatment and recycling.

It should be noted that the SIOABCC, has the purpose of having the necessary information to develop research and knowledge transfer processes, establish scenarios and trends, as well as analyze public policies developed by the federal, state and municipal governments in the field of Water.

The sections are as follows:

- Information and sustainability parameters in accordance with the methodologies of integral watershed management.
- Database on public policies of federal, state and municipal governments.
- Geospatial framework composed of different information agencies.
- Database on laws, regulations and official norms in the different areas of government.
- Theoretical-conceptual and methodological information on issues related to the governance of integral watershed management.

The different sections, which must be updated permanently, are described below.

Information and sustainability parameters in accordance with the basin management methodologies(s)

This first section consists of a database where the information of variables, indicators and sustainability parameters is concentrated according to the requirements of the integral management of basins and their governance.

The information is integrated considering three general categories: environmental, social and economic, of which subcategories are broken down, composed of different variables, information that will help identify the parameters to detect the state and health of a basin.

A. Environmental Category

Subcategories:

- Geology
  Variables: geological mapping, natural resources and zoning of geological hazards.
- Geomorphology
  Variables: geomorphology: edaphological units, relief and psychochemical phases of the soil.
- Soil quality
  Variables: soil quality: bioindicators, psychochemicals, microbiological and contaminants.
- Hydrology
  Variables: climatology, total water balance and quality, water quality and bioindicators.
- Ecosystems
  Variables: Plant cover and fauna.

B. Social Category

Subcategories:

- Population dynamics and territoriality
  Variables: population size by municipality and locality, population distribution, composition, growth rate, mortality, schooling by different age ranges, territorial occupation, migration, minimum levels of social welfare, marginalization and poverty.
- Territorial planning
  Variables: land use, public services and municipal infrastructure, housing, population density and urban, rural and mixed hierarchy.
- Governance and institutional framework
  Variables: governmental structure, problems faced by different forms of government, type of government, evaluation of government systems, laws governing water and innovative approaches.

C. Economic Category

Subcategories:

- Productive economic activities
  Variables: activities of the primary, secondary and tertiary sector mainly focused on the proportion of water used in each of these sectors, and modes of production of goods and services.
- Land use problems
  Variables: land use problems: agriculture, livestock, forestry, mining and urban environment, power generating plants, protection and runoff areas, wetlands, and risk assessment due to land use change.

It should be noted that the subcategories and variables allow to know the health status of a basin, the behavior of the natural and anthropic water cycle, as well as the factors that affect the integral management of the system - basin(s); In addition, if necessary and for the achievement of the purposes of the GEMIC, new subcategories and variables can be integrated into the environmental, social and economic categories.

Public policy database of federal, state and municipal governments

It consists of a database where the existing public policies are concentrated in the three areas of governments, federal, state and municipal, related to water issues; as well as the development of mechanisms that allow its analysis, monitoring and evaluation. This implies, among other actions, the development of studies that account, for example, for local perception of the main problems related to availability, quality, uses and culture of water care, value of the resource, payment for environmental services, etc. ., in relation to government policies, strategies and / or actions that are developed, among other aspects located in the context of the problem of water resources.

Geospatial framework composed of different information agencies

It consists of the cartographic representation of the different variables and indicators related to the categories, subcategories and variables related to the GEMIC. It basically includes maps, letters, atlases, images obtained with remote sensing, digital elevation models and any other information whose spatial component allows its cartographic representation. This can be provided by government agencies of different levels, as well as academic centers, civil society and individuals, both nationally and internationally. It is important to emphasize that this type of information must be accompanied by additional information or metadata, which allows monitoring the original source of the information and, if applicable, assess whether it meets the minimum quality standards, to integrate it into analysis processes, management and decision making.

Some of the Mexican government agencies that provide high-quality and regularly updated cartographic information are INEGI, CONABIO, INE, SEMARNAT, CONAFOR, CONAGUA, among others. Some academic institutions such as UNAM, UAM, IPN and several state universities produce this type of information as a product of their research. Both national and international NGOs have very valuable environmental and socioeconomic cartographic information, such as WWF, Conservación Internacional, The Nature Conservacy and PRONATURA; In addition, some international agencies also have important collections such as NASA, NOAA, UN, and that allow to obtain even historical series of data from several decades.

Database on laws, regulations and official norms in the different areas of government

It is based on the permanent elaboration of an information matrix on laws, regulations and official norms of federal, state and municipal governments, based on the theme and problem of water, related to the following areas: availability of the resource in quantity and quality ; operation and operation of the hydraulic system and / or distribution networks; regulation of the supply and demand of water resources, rational and conjunctive use of surface and groundwater; provision of drainage, sewage treatment and recycling; payment for domestic, commercial and industrial water service; as well as those related to the protection of ecosystems and their goods and services, among others.

Theoretical-conceptual and methodological information on issues related to the governance and integrated management of watersheds

It consists of a database where information on methodologies of use, governance and integral management of water and/or basins is concentrated; its theoretical-conceptual approaches, as well as articles, books and brochures related to the extensive theme and problems of water, among other topics.

Definition of the diagnosis and the problem under a comprehensive watershed approach

Factors for determining the diagnosis and the problem

The so-called basin methodologies cover a series of basic analysis factors for their integral management. From the debate that arises from the Rio meeting (1992), a large number of authors analyzed and established a consensus on the factors that account for the health of a basin, although these are located in different parts of the world, (see Heathcote 1998), and also, are necessary for the management and management of basins.

From the above, three basic factors have been constructed, which are related to the categories of environmental, social, economic and cover the phases of the natural and anthropic water cycle, which facilitate determining both the diagnosis and the problem of a basin It is also considered that, from these, the information of the different sections that make up the SIOABCC can be organized and integrated. Next, the factors for the analysis in the context of the integral management of basins and their management are indicated:

Water availability: fresh water availability; aquatic habitat and wetlands; biodiversity and ecosystem connectivity; extraction in aquifers and surface waters; natural disasters and risk atlases (floods and droughts); climate change; Water payment; concession of bodies of water and others.

Water quality: water quality in rivers, springs, groundwater, lakes, lagoons, oceans, coasts, among others; preservation and / or conservation of water-related ecosystems; water laws and legislative reforms of federal, state and municipal governments; sources of pollution; health risks and others.

Institutions for water management, society and economy:

Government water coordination networks and their functions; regional profile of water users; Government institutions related to water; policies, planning, programs and projects; financing and costs; infrastructure, distribution networks, sanitation and treatment; territorial ordering; population dynamics; uses of natural resources; means of production; change of land use; water rights and permits; minimum levels of well-being and others.

Diagnostic process and problem determination:

This phase is based on the analysis and evaluation of the geographical space covered by the basin, in accordance with the analysis factors for the integral management of basins and their management established in the previous point. This phase may have as a guide a series of questions that are more specific than those raised in the construction of the systemic vision of the basin, which may be: what is the availability of water in quantity and quality? What are ecosystems? related to water ?, in what state are they ?, what are the social and economic conditions of the basin ?, what are the means of production and the impact on environmental goods and services ?, what are the public policies and the regulatory framework in the exercise of basin management and management and its efficiency? among other. Of special interest is to

evaluate the anthropization of ecosystems, that is, to determine the impacts that different users of water or human activities have on the natural environment of the basin.
To establish the diagnosis and problem of a basin, it is essential to identify and collect sources of information, including studies that have been done on various aspects of the behavior of the natural and anthropogenic water cycle; the formulation and development of basic disciplinary and / or specialized studies; the development of field work; the systematization of information; and the presentation of the preliminary results in accordance with all the participating disciplines, as well as the development of all those activities that are required for this purpose, (see García 1994, 2006 and Fenlzl 2010).

Considering the magnitude involved in making a comprehensive diagnosis, it must necessarily arise from previous studies. This means that in addition to developing the traditional phases for diagnosis, the following aspects should also be considered:

a. Going to reconstruct the history of the system / basin, that is, the studies should focus on the identification of processes and mechanisms that represent a concatenation of events that have happened in terms of time and space. The above is established according to the factors for the analysis of the integral management of basins and their management, that is, availability and quality of water, the aspects related to the institutions for water management, society and economy, as well as each one of the elements that integrate them.
b. To focus on the detection of the deterioration processes that have meant a progressive deterioration in the system / basin in terms of the environmental, social and economic components and in the factors established in the previous point; as well as specifically determine what are the causes that produce them or tend to produce it.
c. Clearly identify the anthropogenic factor, which means analyzing the sequence of events that can determine complex problems, where multiple events are interrelated.
d. Also consider alternative proposals that could be implemented, which are prospective. This is directed to the analysis of the evolution of the system and is based on the predictability based on a new system that may arise when implementing modifications and foresee new processes that will be developed when new strategies and actions are introduced, since according to the theory of the systems, any modification in a category or sector of the system induces changes in the structure, in different levels, degrees, temporal scales, etc.
e. It should be noted that this research phase to establish the diagnosis of the basin / system, which is aimed at determining comprehensive management strategies, is not linear. It is likely that it is necessary to repeatedly return to the process that involves studying situations and / or problems, variables and indicators or include other variables that have not been considered in advance.

Determination of the watershed problem

Based on the diagnosis and with the participation of all the members of the research team, the process of general recognition of the problem of the basin is established, developing the following activities:

A. With the support and foundation of studies that have been carried out and the information that has been collected on the various factors for the integral management of watersheds and their management, which are the availability and quality of water, as well as the institutions for the management of water, society and economy, established in advance, develops an analysis process that allows to reconstruct the history of events, situations and phenomena that have occurred in the system / basin (s).
B. Based on the foregoing, the first approach on the operation of the basin related to the analysis factors for the integral management of basins and their management is established; as well as the conditions that intervene in the microscopic, mesoscopic and macroscopic dimensions of the complex system established above, among other aspects.
C. According to the first determination of the operation of the system, the working hypothesis about the behavior of the system is raised. This will serve to reformulate or specify the core questions in terms of the functions of the categories - Environmental, Social and Economic - (ASE), and their relationship with the factors for the analysis of the integral management of basins and their management; and / or raise new questions that guide the understanding of the total functioning of the system.
D. Based on the above, it will be possible to identify the problem to be investigated in each ASE category and the factors established in advance, to validate or rethink the hypotheses about the functions in the system. This can be used to identify new studies in specialized subjects that require greater depth.
E. Subsequently, the necessary disciplinary and / or specialized studies are carried out on problems referred to in the previous point, which are located in the context of the interrelations between the ASE categories.
F. From the development of the previous points, a first integration of the results of the diagnosis can be established to determine the general problem of the system / basin, that is, the one that derives from the interrelation and interdependence of the ASE categories. This will allow to redefine the system / basin and reformulate the specific questions raised and / or raise others.
G. After the above, the problem to be investigated and redefined each ASE category is re-identified, to validate or rethink the hypotheses about its functions in the system. This allows to determine new studies in specialized subjects to obtain a greater depth in the phenomena established by the interrelations between the ASE categories.

The previous phases can be carried out successively until a clear and coherent explanation can be obtained about the integral problem of the system / basin (s), which must answer the series of questions that have been raised in the process for the determination of diagnosis and problems.

It should be noted that the problem is based on a process of integral analysis (quantitative and qualitative), which means investigating and / or studying various aspects such as the reconstruction of the system, the “reading” of interrelation and interdependence of its categories, that is to say , environmental, social and economic, establishing a deeper study on the factors of analysis for the integral management of basins and their management, among other actions. The purpose of the foregoing is aimed at establishing a network of facts and / or circumstances that allow determining the key elements where the problems lie.

From the determination of the state of the system / basin (s), and the underlying problem, which is the initial situation that the group of researchers faces, the next step is to establish a proposal for change and / or intervention that solves the problem, that is, determining a diachronic process to formulate possible transformations.

Intervention strategies for gemica

In the context of the management for the integral management of basins from the perspective of the so-called sustainable development, the development of strategies must consider a new state of the system / basin (s), which implies therefore its evolution, and must also include a redefinition of the vision of the complex system established at the beginning of the methodological process. This implies designing the ideal state of the system, that is, the desirable functioning of the basin; and from this new vision the type of transformations that must be put in place for its implementation can be established.

For the above, it is necessary to develop various analysis procedures on what factors have to be modified and how the processes that here and now determine the functioning of the system can change, also establishing the relevance of the changes, their relevance and feasibility.

At this time, it is when policies, intervention strategies and change actions are defined; alternatives, which will lead to a new state of the system, that is, to its evolution, which means improving the problem found in the diagnostic study developed. Next, three general moments of the strategic development process for the management of integral watershed management are described.

Development of the strategic intervention process

For this activity the following stages are established:

1. Based on the result of the diagnosis and the problem that were defined in an integral manner, the priority management objectives for the integral management of basins are established, explaining its scope and the modifications related to the intervention in the system; as well as the development of the financial project and the specification of the resources that are required for the development of the strategies.
2. An important aspect is the analysis of the public policies that are being developed in the three levels of government, to locate the context in which it is proposed to develop the strategies.
3. It is essential to establish an analysis under the systemic approach of each strategic proposal regarding the following aspects:

A. How the proposed changes in one category will affect others, for example, how environmental strategies impact on social and economic or vice versa, that is, analyze the possible repercussions in terms of intervention (strategy development) in any ASE category, over the others.

B. What would be the new interactions between the categories of the system (ASE), through the intervention / development of the strategies, which can modify the system / basin.

C. From the previous one, the characteristics that the operation of the new system / basin could adopt, based on the intervention proposed in each of the categories of the complex system / basin (s), can be “modeled”.

Strategic areas of action for the integral management of watersheds

In the understanding that a basin can be approached as a complex system that is integrated by three categories (ASE), which are in a constant interrelation and interdependence, and that in these, an exchange of constant flows of energy and matter (metabolism)), then the areas of attention are multifactorial since they relate, in general terms, to the functioning of water-related ecosystems, the supply and demand of different water users, the modes of production of goods and services, the impact of the anthropic factor, the resilience of ecosystems, among other aspects.

As stated, the diagnosis and detection of the problem of the functioning of the system / basin (s) established, serve to design the strategic and intervention model of the GEMIC, and the ASE categories and the factors of integral management analysis and Management are the structure of said model. Based on the above, a strategic intervention model of GEMIC is identified. (See figure 1).

Figure 1

It should be pointed out that the central purpose of the strategies is to stop and, if possible, reverse the processes of deterioration of ecosystems and their goods and services, intervening in the causes, so that all water users and the ecosystems themselves have the water resource in sufficient quantity and quality in the present and the future. The development of the strategic intervention model for the GEMIC and the projects that integrate it, are aimed at addressing the following areas, which are shown in Table 1.

Table 1 Strategic intervention model: general projects	
• Hydrology and Hydrography • Underground circulation • Snowfall Flow • Reservoir Regulation • Erosion, transport and sedimentation • Floods and droughts • Pollution of water sources • Biodiversity and preservation of resource-related ecosystems	• Connectivity of natural ecosystems • Irrigation and productive uses • Sustainable human community development • Coasts and wetlands • Good government • Others

Approach to the implementation of the strategies

The strategic intervention model of the GEMIC can be established in accordance with the governance approach that implies that society, higher education institutions and the government establish and develop participation schemes where public policies are based on the needs and in urgent and / or priority problems in a timely manner; that the society supervises jointly with the scientists the results of its implementation, and that the latter develop and / or generate knowledge that propose solutions. This implies communication processes, development of community and government projects, monitoring of actions, among other multiple aspects. The main actions in this regard are:

- Propose to those responsible and / or decision makers at the governmental level, according to the different strategies that favor the solution of the problems detected in the natural and anthropogenic cycle. This can be developed based on the information that supports the trends and future scenarios established by the diagnoses and problems identified. The foregoing may foster a culture of foresight, a fundamental task for higher education institutions.
- Disseminate to society in general and to the government, the information and / or aspects related to the behavior of the phenomena related to the most urgent water problems, their tendencies and probable scenarios, whether mediated and / or future. The company has the right to have truthful and timely information, especially when dealing with a national security issue in Mexico.
- Build governance networks that influence decision-making, that is, with the participation of government officials, the development of different mechanisms that allow the establishment of citizen collaboration networks at the local level is encouraged. The identification of social leaders and / or citizens with an authentic commitment to work and collaborate for a common social good, is a work of great relevance, since the political landscape and the way of governing have to evolve towards other ways of articulating

collective interest. Although higher education institutions carry out multiple projects in the context of environmental problems, it is necessary to organize networks with social actors that ensure their participation in decision-making processes in local areas and influence the design and development of public policies of governments.

Evaluation of indicators and determination of sustainability parameters for the GEMIC

It is considered essential to establish a culture of measurement and evaluation of changes resulting from the development of policies, strategies and actions in the different areas of the strategic intervention model of the GEMIC, which must necessarily be reflected in the quantitative and / or qualitative evaluation of indicators that account for the evolution of the system / basin.

This implies determining whether the natural and anthropogenic water cycle has changed and in what phases of it have been carried out, for example, there is a greater availability of water in quantity and quality; If the deterioration processes in the system / basin (s) are being reversed, this can be reflected in greater connectivity in the ecosystems related to the water resource and also in the identification of the new processes that have allowed it; how the anthropogenic factor has varied and what activities of water users are related to this modification, among other aspects.

It is proposed that one of the most relevant challenges is to implement measurement and evaluation processes that identify changes in social, environmental and economic terms, and establish the elements related to environmental rationality, whose context as we have mentioned, is sustainable development. The foregoing is based on the definition of indicators, parameters, indices, ranges, etc., related to the sustainability of the process, a matter that is basic to verify its evolution of the system / basin(s).

Measure to evaluate the process: towards environmental rationality

Environmental rationality in a basin is a fundamental factor in the design of GEMIC strategies. This rationality is a political and social process that must be built and is based on the reorientation of the tendencies of overexploitation of the natural resources of the system, which means constructing a new alternative development scheme that proposes that the anthropogenic factor has less impact. on the capacity of recovery, regeneration and / or conservation of the optimal state of the ecosystems of the basin.

Based on the above, the need to quantitatively and qualitatively measure the results of the strategic intervention and define parameters related to the sustainability of the system / basin (s) is established. The concept of resilience is included, which is defined as the degree to which a system / basin recovers from the action of a stimulus, that is, its ability to return to the state prior to the alteration Maass (2007).

This can be a reference point to measure and evaluate the system tends to a process of "self-regulation" in terms of the interactions of the environmental, social and economic components, this refers, mainly to the establishment of those actions that allow that the anthropic factor is not greater than the recovery factor of the ecosystems that generate the natural resources of the basin(s).

It should be noted that, evaluating indicators, parameters and ranges in the GEMIC necessarily implies measuring the processes related to the resilience of ecosystems, over time, to verify that intervention strategies in the system / basin(s), allow rationality environmental, that is, the sustainable and sustained use of natural resources.

The measurement for the evaluation of the GEMIC intervention model

This process is considered as a second stage of diagnosis of the system / basin (s), which is also carried out in an integral way, and allows us to measure and evaluate the evolution of the system, that is, to measure how our problem has varied in the three factors for the integral management of watersheds and their management that are availability, quality and institutions for water management, society and economy. This is aimed at determining if the basic conditions that determine the "health of the basin" have changed and, if management has modified aspects related to the demands of different water users, which refers to the minimum levels of well-being social of the inhabitants of the region. And it also aims to propose trends and scenarios under prospective approaches that serve decision makers at different levels of government and society in general.

From the above, a series of stages are established that can be used to develop the measurement, determination of parameters and evaluation of the intervention in the system / basin (s), which are described below:

A. The strategic intervention model of the GEMIC, is analyzed and recapitulated jointly among the members of the research group, to analyze the operation of the system / basin, after its implementation.
B. Based on the foregoing, the general process is agreed to define the parameters that measure sustainability, related to the variables and indicators of water availability and quality, as well as those related to water management institutions, society and economy It should be noted that, these are the fundamental references to evaluate the efficiency of the development of the strategic intervention model of the GEMIC, and the different projects that are developed in the fields of: hydrology and hydrography; underground circulation; snowfall flow; reservoir regulation; erosion, transport and sedimentation; floods and droughts; contamination of water sources; biodiversity and preservation of ecosystems related to the resource; connectivity of natural ecosystems; irrigation and productive uses; coasts and wetlands; sustainable human community development; good government; among others.
C. This process must include the selection, definition and / or approach of the set of indicators that will allow evaluating the intervention in the system, as well as the definition of the parameters, indices or ranges in the context of sustainability. The understanding and operational definition of these concepts such as indicators, parameters, indices, ranges, etc., and their differences is a central task in the GEMIC, therefore, all researchers in the working group must participate.
D. Because the evaluation of the implementation of the strategic intervention model and its management is essential, a systematic measurement process must be developed with a consistent methodology, which allows for high reliability for a given period of time; as well

as obtaining time series of data, which allow the development of a second phase of strategic intervention in the system / basin (s).

E. It is pointed out that the indicators must be defined according to the intervention tactic, that is, according to the purposes and objectives of the GEMIC and the results of the development of the strategic intervention model, and its impact on the three analysis factors for the integral management of watersheds and their management, which were diagnosed, from which the problem arises comprehensively. This phase is considered as "control" or "pilot" of the intervention process of the system / basin (s). This can help to know if there really are changes, and if the system has the capacity to evolve.
F. A central part is the definition of sustainability parameters of the system / basin (s). This means measuring the metabolism of the energy expenditure of the system, determining parameters or indices of resilience. In this regard, it can be determined whether the economic activities carried out in the basin depend heavily on natural resources, since economic rationality is significantly weighted, which therefore does not add a direct social benefit to the population; In addition, there are no actions aimed at conserving water-related ecosystems. We can measure and evaluate that there is no real reconstruction process and / or positive evolution of the system / basin (s), so we can point out that it is not sustainable. From the above, future trends and scenarios can be established, and new intervention and management policies and strategies proposed.
G. The above refers to the development of studies and / or research aimed at measuring the activities that water users carry out in the system / basin (s), to develop indices of the anthropic factor or resilience, after the intervention process. This is essential to have relevant information to support the monitoring of the “health” status of said system and its permanent changes or transformations.

In summary, it is essential to determine whether strategies have been established that allow for sustainable development in the context of integral watershed management. To do this, indicators should be measured, and parameters and indexes established to verify if the development process is really sustainable, that is, if the process promotes the well-being of people who add economic value to natural resources, and if they are really protecting them. and / or conserving, and therefore, the effect of the entropic factor, on the goods and services of ecosystems, issues that are the focus of this section is being diminished.

The academic work carried out at the Water Observatory for the State of Veracruz, ABCC (Water, Forests, Basins and Coasts), requires the political will to call the university community to participate and establish the required changes and ensure the social function of the University of Veracruz facing the nascent century. The GEMIC methodology is aimed at supporting the creation and transfer of a more just and humane social and economic development, which allows social equity and preserves the habitat and wealth that represent the natural assets of the state of Veracruz and the country.

Acknowledgments

To the members of the Water Observatory for the State of Veracruz, OABCC (Water, Forests, Basin and Coasts) for their permanent collaboration, to Ana Isabel Suárez Guerrero PhD for her contributions and to Norbert Fenzl PhD of the Altos Core Amazonian Studies of the Federal University of Pará, Brazil, for their valuable comments and observations in the process of construction of the GEMIC.

References

Fenzl N., (2010). The Sustainability of Complex Systems, Basic Concepts for a Sustainable Development Science, Theoretical and Practical Aspects. Belém: Federal University of Pará / Center for High Amazon Studies.

García, R., 2000. Knowledge in Construction. From the formulations of Jean Piaget to the Theory of Complex Systems, Gedisa, Spain.

______, R., 1994. Interdisciplinarity and Complex Systems. In: Social Sciences and Environmental Training (E. Leff, Ed.) Gedisa, Barcelona, pp. 85-124.

Heathcote., I, 1998. Integrated Watershed Management: Principles and Practice, John Wiley & Sons, Inc., USA.

Maass M., 2003. General Principles on Ecosystem Management. In: Conservation of Temperate Mountain Ecosystems in Mexico (Oscar Sánchez, Ernesto Vega, Eduardo Peters and Octavio Monroy-Vilchis, Eds.) National Institute of Ecology, SEMARNAT, Mexico, pp. 117-136.

Chapter 7

Landscape geography: a holistic approach to disaster risk management

Ana Cecilia Travieso Bello

Abstract

The systemic, hierarchical and historical evolutionary approach of landscape geography allows the integration of physical, ecological, economic, socio-cultural and political factors associated with disaster risks, as well as analyzing the dynamics and evolution of landscape units in space and weather. It is proposed that these units be the basis for the development of development planning instruments and that they incorporate comprehensive risk management, through prevention, mitigation and adaptation strategies. These strategies should be aimed at generating capacities in the population to face extreme events, minimize losses and damages associated with these phenomena and at the same time, maximize profits in productive and welfare terms.

Introduction

Disaster risk is the probability of future damages and losses, associated with the occurrence of a harmful physical event, called danger or threat. It expresses and concretes with the exposure of the human population, production and infrastructure to the possible impact of the various types of physical events and their vulnerability, that is, the conditions that predispose society and its livelihoods to suffer damages and losses. . Therefore, the level of risk will be determined by the intensity and duration of physical events, the degree of exposure and vulnerability (Narváez et al., 2009).

The threats that society potentially faces are very wide and varied, these are classified as natural, socio-natural and anthropogenic. The natural ones are associated with geological, geomorphological, atmospheric and oceanographic dynamics (earthquakes, volcanoes, hurricanes and tsunamis); socio-naturals are produced by the intersection or relationship of the natural world with social practices (deforestation, land use changes, inappropriate management practices, among others), such as many cases of floods, landslides and droughts, while Anthropogenic are the product of human activity, among which are explosions, conflagrations, spills of toxic materials, air, land and water pollution by industrial products (Lavell, 1996).

A disaster is the materialization or manifestation of risk, where the levels of damage and losses exceed the ability of society to face, absorb and recover from impact (Gómez, 2010), significantly disrupting the normal functioning of society and affecting its daily life.

The incidence and impact of disasters worldwide have registered a vertiginous increase in the last decades of the 20th century, observing an increase of up to six times in losses associated with disasters of all kinds during the last forty years and 500% in the losses associated with hydrometeorological phenomena in the last seven years (Lavell et al., 2003). In the case of Mexico, the reports of disasters during the period 1970-2009 showed an increase from 1990, where more than 60% are associated with hydrometeorological phenomena, particularly floods and droughts, which affect all federal entities.

The destruction of homes is mainly due to rains and floods (66%), earthquakes (20%) and storms, while losses of human lives mostly occur due to earthquakes and epidemics (37%), followed by pollution and floods (Mansilla, 2012). It is important to highlight that intense rainfall and flooding are much more frequent phenomena than earthquakes and epidemics, therefore, they could potentially cause a greater number of disasters, limiting the adaptive capacity of the population and resilience. The latter defined as the ability of ecological and social systems to absorb disturbances, retain the same basic structure and the ways of functioning, self-organization and adaptation to stress and changes (Parry et al., 2008).

Currently, there are three closely related crises, which are the economic, energy and climate change crises, so an increase in the number and intensity of disasters is expected, however, each territory will respond in a manner different from the three crises depending on the interaction of natural, socioeconomic and cultural factors, which model different degrees of social vulnerability (Travieso-Bello and Bocardo-Valle, 2012).

Many authors agree that disasters are unresolved issues of development; in general, they affirm that the social, political, economic and institutional conditions, resulting from a development model imposed on the planet in a unilateral and hegemonic way, favor locally the generation of favorable conditions for the occurrence of disasters, however the decision makers they still do not incorporate these judgments to modify the practices in which said development model is implemented in their local scenarios (Thomas, 2011).

If the occurrence of dangerous physical phenomena is understood as particular moments within natural dynamics, these can be analyzed and therefore, included in development planning, guiding risk management to minimize losses and damages associated with these phenomena and at the same time, to maximize profits in terms of production and well-being, through the rational and sustainable use of resources (Narváez et al., 2009).

Disaster risk management is a social process, whose ultimate goal is the forecast, reduction and permanent control of disaster risk factors in society and must be integrated into the achievement of human, economic, environmental and territorial development goals, sustainable (Narváez et al., 2009). For this to happen, a set of policies, actors, strategies, instruments and actions that seek to structurally eliminate (prevent), as well as mitigate and reduce, conjuncturally, the elements and levels of exposure of communities against those potentially events must be articulated destroyers, while increasing their ability to respond, adjust and recover from adverse effects (Thomas, 2011).

Risk management can be classified as corrective, prospective and adaptive. Corrective management intervenes on the existing risk and tries to reduce it; Prospective management acts on a risk that does not yet exist, avoiding or reducing it, while adaptive management does so on non-reduced or accepted risk, minimizing probable damages and losses, by applying measures that increase resilience and adaptive capacity (Gomez, 2010).

In this context, the landscape geography is analyzed as a trans-discipline that allows to study the dynamics and spatio-temporal evolution of disaster risk factors (dangerous physical events, exposure and vulnerability), and include them in development planning to achieve comprehensive disaster risk management more effective.

Application of landscape geography in disaster risk analysis

The geographical landscape is a general scientific category of a transdisciplinary nature, which can be defined as a complex, open, space-time system that originates and evolves in the nature-society interface, with a constant exchange of energy, matter and information. Its structure, functioning, dynamics and space-time evolution reflect the interaction between the natural, technical-economic and socio-cultural components (Mateo et al., 1994), therefore, it is the scenario where disasters occur and therefore, where the risk It must be analyzed and managed comprehensively.

The geography of the landscape allows to carry out a synthetic and integral analysis of the characteristics of a territory, based on the identification of the vertical and horizontal structure of the landscape. The vertical structure includes the abiotic, biotic and anthropic components of the landscape, while the horizontal structure is the spatial arrangement and distribution that results from the interaction between its components (Carbajal et al., 2010).

The variability of the physical-geographic landscapes responds to the spatial distribution of the landscape indicator elements, (lithology, relief and climate), which are complemented by the differentiating components, which are soil, vegetation and land uses (Carbajal et al., 2010). The landscape approach gives equal weight to all components and integrates them into a spatial perspective that facilitates clarifying the inherent properties of the geosystem as a whole (Priego et al., 2004). In the case of the territory of Mexico, the great diversity of physical-geographical landscapes is determined mainly by the spatial variability of natural components, especially climate changes, as well as the complex geological-geomorphological evolution (Bollo and Hernández, 2008) , together with the different types and degrees of modification, caused by human activities.

The landscapes are dynamic, so they naturally change over time, however, nowadays most of the changes are the result of human intervention, that is, of the activities aimed at the use of the land (mining or quarries, forestry), the construction of buildings and structures (power plants, industrial areas, routes and urbanizations), changes in land management (increased agricultural use, use of irrigation systems), alterations in processes of production and emissions (textile, food and chemical industrial plants), the means of energy transmission and water supply, among others (Castelli and Zapallasso, 2007).

The horizontal and vertical structure of the landscape, as well as the indicator and differentiating elements are essential for risk analysis, since the shapes of the relief, the lithology, the climate, the distribution of the bodies of water, the drainage network, the type of soil and vegetation, are natural factors that interact with each other and shape the geological, geomorphological and atmospheric dynamics in the territory, therefore, condition the occurrence of dangerous physical events.

In addition, human activities extract natural resources for consumption, the production of goods and services and the construction of infrastructure, which produces changes in land use and traditional management practices and generate large amounts of waste that is difficult to degrade, that alter biogeochemical cycles.

This modifies the spatial arrangement of the natural components of the landscape and therefore, its operation, mainly losing the environmental services provided by ecosystems. These services were classified by MEA (2005) as support, provision, regulation and cultural; those that are more closely related to risks are the regulation services, since they regulate gases, climate, water, prevent disturbances and contribute to the treatment of waste.

On the other hand, the landscape geography approach allows locating in the territory the human population, infrastructure and productive activities exposed to the different types of potentially dangerous physical events, as well as the conditions of vulnerability of the population. To achieve the integration of this information, it is proposed to use indexes that reflect the degree of exposure and vulnerability, which can be represented spatially for federal entities, municipalities and localities. The integration of these indices will depend on the availability and quality of the information for the different levels of analysis.

The classification of landscapes has a taxonomic and hierarchical structure, which allows to know the ecological-geographical integration of a territory. The spatial differentiation is expressed in the existence of taxonomic units of different rank, distinguishing sectors, localities, regions, subregions and facies, the latter two are the minor units of the landscape and are represented cartographically on a detailed scale (Priego et al., 2004).

Disaster risk analysis requires articulating different scales or levels of analysis, since many physical and biological processes are analyzed at the basin level or physiographic region, while economic, sociocultural and political processes, due to the origin of the data, are studied. at the level of locality, municipality and federative entity, which has traditionally hindered its spatial representation.

On the other hand, the complex nature of risk and the processes involved in its construction encompasses the motivations and decisions of multiple social actors, functioning in accordance with diverse sectoral interests and with varied territorial reference and influence points. The local, the regional, the national and the international represent different spheres, with diverse roles and functions, which must operate in a related and concatenated way in the search for integrated and effective risk reduction, forecasting and control schemes associated with multiple threats. (Lavell, 2002).

The landscape approach allows to articulate the multiple scales and social actors, integrating the information in the landscape units, which allow combining natural and administrative boundaries, as well as analyzing the natural and anthropogenic dynamics and evolution in space and time, through a synthetic and integral analysis of all components, granting them the same specific weight and explaining the characteristics and interactions of the geosystem as a whole, according to Priego et al. (2004).

The landscape is the physiognomy, morphology or formal expression of space and territories, reflecting the vision that the population has about their environment, integrates scientific and emotional language, allowing mutual reinforcement of geographical knowledge and cultural identity (Mateo y da Silva, 2007), so it is appropriate for the analysis of the social perception of risk, defined as the social representations around threats, vulnerability and their causes, as well as the capacity for self-management, the role from the social and private sectors, the academy and the different levels of government (municipal, state, federal) in the possible solutions.

The social perception of risk includes the different ways in which populations and organizations ration, organize, systematize, objectively and subjectively, their knowledge of threats, vulnerability and risk, in such a way that they influence their location decisions , productive diversification, forms of self-protection (structural, behavioral, security, etc.), among others. The factors that can influence the different perceptions are varied, highlighting class, ethnicity, race, gender, age, educational levels, religious beliefs, previous experiences and organizational participation, among others (Thomas, 2011).

The analysis of social perceptions allows to explain behaviors and identify factors that prevent processes that go from the decision to protect themselves to social (political) organization in favor of changes in public policies (Thomas, 2011).

Risk management and development management from landscape geography

The relationship between risk management and development management has been seen in two dominant ways; the first considers that risk must be “integrated into” or “mainstream in” development management in its different sectoral or territorial expressions, therefore , is based on the idea that development improves or is substantiated and strengthened to the extent that risk issues are explicit and present in the design of development policies, strategies and instruments.

The second way to see this relationship is the combination and concatenation of the two themes (risk and development), through more holistic or deductive approaches, that is, not summative. This vision establishes that there is no cross-cutting theme, but an integral one, since risk is considered an essential and constitutive aspect of development, therefore, there can be no true development without risk prevention and reduction (Narváez et al., 2009). Although at present the first vision is the dominant one, both the discourse and the practical one, the second one, is the one that really contributes to a sustainable development.

In this context, it is proposed that the classification of the physical-geographic landscapes and the definition of taxonomic units of different rank be the scientific basis for the elaboration of the atlases of dangers and risks (at national, state and municipal level), the plans of contingency and climate action, as well as for the definition of the environmental management units of the ecological and urban planning programs, which must incorporate the risk analysis in an integral manner.

It is also vitally important that the information contained, both in the atlases and management programs, be incorporated into national, state and municipal development plans, as well as public and private investment projects, so that it not only contributes to corrective risk management, but also to prospective and reactive, avoiding the emergence and consolidation of new risk factors in the territory, as well as increasing the resilience and adaptive capacity of the population, respectively.

Conclusions

The systemic, hierarchical and historical evolutionary approach of landscape geography allows the integration of physical, ecological, economic, socio-cultural and political factors associated with disaster risks, as well as analyzing the dynamics and evolution of landscape units in space and weather. These units can be the basis for the development of hazard and risk atlases, contingency and climate action plans, as well as ecological and urban planning programs, which must be incorporated into development plans. In this process, not only corrective risk management, but also prospective and reactive management should be considered.

On the other hand, the analysis of the social perception of risk in the landscape reflects the vision of the population about their environment and their cultural identity, this together with the processes of social and institutional agreement, which incorporate the different socioeconomic strata, the various sectors and levels of management and public and territorial action, contribute to the successful application of public policies that promote the inclusion of comprehensive risk management in sustainable development, through prevention, mitigation and adaptation strategies that generate capacities in the population to face extreme events, minimizing losses and damages associated with these phenomena and at the same time, maximizing profits in productive and welfare terms.

References

Bollo M. and J. R. Hernández, 2008. Physico-geographical landscapes of the northwest of the state of Chiapas, Mexico. Geographic Research 66, pp. 7-24.
Carbajal J. C., J. R. Hernández and M. Bollo, 2010. Physical-geographical landscapes of the Chilpancingo-Azul Tourist Circuit, Guerrero state, Mexico. Geographic Research 73, pp. 71-85.
Castelli L. and V. Zapallasso, 2007. Landscape planning and conservation. Nature for the Future Foundation. Buenos Aires, Argentina.
Gómez M. A., 2010. Conceptual framework under which the experiences of risk management and adaptation to climate change in Peru have been developed. In: Lessons learned from Risk Management in Planning and Investment Processes for Development (Ministry of Economy and Finance, Peru; Piura Regional Government; International Strategy for Disaster Reduction (NU / EIRD); Deutsche Gessellschaft für Technische Zusammenarbeit (GTZ), Eds.) German Development Cooperation - GIZ Agency in Peru, Lima, Peru, pp. 33-35.
Lavell A., 1996. Environmental degradation, risk and urban disaster. Problems and concepts: towards the definition of a research agenda. In: Cities at risk (M.A. Fernández, Comp.), La Red, USAID, Lima, Peru, pp. 21-30.
_____, A., 2002. Risk, disaster and territory. The need for regional / transnational approaches. Social and Political Yearbook of Latin America and the Caribbean 5, pp. 140-147.
_____, A., E. Mansilla and D. Smith, 2003. Local risk management. Notions and precisions around the concept and practice. Coordination Center for the Prevention of Natural Disasters in Central America, Guatemala.
Mansilla E., 2012. Disaster effects inventory system. Version 2012.05.1099. Recovered from: http://online.desinventar.org/
Mateo J. M., V. da Silva and A. P. Brito, 1994. Analyze the country as the basis for a Geo-Environmental Organizational Strategy: Corumbatai cspl Colectario 004 Environmental Planning, University of São Paulo, Brazil, pp. 57-105.
_____, J. M. and E. V. Da Silva, 2007. Landscape geoecology, as the basis for environmental analysis. Electronic magazine of Prodena, Fortaleza 1 (1), pp. 77-98.
Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and human well-being: Our human planet. Summary for decision makers. Island Press, Washington D. C.
Narváez L., A. Lavell and G. Pérez, 2009. Disaster Risk Management: A process-based approach. General Secretariat of the Andean Community, Lima, Peru.
Parry M., O. Canziani y J. Palutikof, 2008. Climate Change 2007: Impacts, Adaptation and Vulnerability. Workgroup II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.Cambridge University Press.
Priego A. G., H. Morales and C. Enriquez, 2004. Physical-geographical landscapes of the Lerma-Chapala basin. Ecological Gazette 71, pp. 11-22.
Thomas J. E., 2011. Social development and risk management: a historical contradiction? Geography Magazine Norte Grande 48, pp. 133-157.
Travieso-Bello, A. C. and A. Bocardo-Valle, 2012. Social vulnerability to globalization and climate change: The case of Veracruz municipalities. In: Electronic Book of the First Ibero-American Congress on Regional Development: World Positioning and Strategies, 17th. National Meeting of Regional Development in Mexico, AMECIDER 2012, UNAM, Mexico D. F, Mexico.

Chapter 8

Relevance of GHG (greenhouse gas) emissions in Veracruz and its calculation method

Carlos Manuel Welsh Rodríguez
Carolina Andrea Ochoa Martínez
María Tania García López
Dainiz Evlyn Hernández y Hernández
Saraí Guzmán Rojas

Abstract

In Mexico, the state of Veracruz regarding climate change has two GHG inventories and they have impacted Veracruz public policies. Its relevance is focused on the value of information for decision-making in the public and private sectors, the methodology applied is that established by the PICC (Intergovernmental Panel on Climate Change).

In Veracruz, about 98% of the country's secondary petrochemicals are processed, together with a production of electricity close to 20% of the national total; GHG emissions represent about 8% of the country, it is the third most populous state and there is no industrial sector with significant activities like other states such as Nuevo León or Jalisco.

For 2008, Veracruz generated 44,736 Gg of CO2 equivalent, the sectors that contribute the most GHG are, in descending order: energy, livestock production and oil and gas industry. Noting the impacts of the inventory in the planning of the environmental policy of Veracruz, it was used as an instrument to build the Veracruz Development Plan 2011-2016, from which the initiative of Law on mitigation and adaptation to Climate Change was discussed.
Keywords: GHG, Public Policy, Planning, Development.

Veracruz’ Plan for Climate Change

The University of Veracruz, at the express invitation of the National Institute of Ecology, coordinated academics from various institutions, including UNAM and the Institute of Ecology, AC, to develop a climate action plan, pioneer for its structure, design and methodology of development, being the first nationally.

The primary objective of the plan is to provide reliable information, understand the phenomenon and its possible impacts, which in turn provide a truthful source of where decision making is possible and in the best case the construction of public policies (PVCC, 2008) to society groups such as: political, social, economic, cultural.

The academic work generated a series of studies that can be grouped into the following areas: Emissions (emissions and scenarios), Climate, Climate Variability and Climate Change, Vulnerability of the Biophysical System, Economy and Society; Finally, a synthetic document was generated which, in the framework of the 2010 electoral process, was handed over to the candidates for Governor of the state.

As a summary, some outstanding points in each area are commented, for example, future scenarios show an increase in temperature in the state and this indicates that there will be an increase in climate risk, given that projections in temperatures and precipitation have resulted be similar or superior to those presented during extreme events in the past (Palma et al., 2008).

As for the biophysical system, Veracruz is a coastal state of the Gulf of Mexico, and in that basin the PICC points out that extreme events will be accentuated (droughts, heavy rains, greater incidence of hurricanes and tropical depressions) in the years to come.

Rafael Palma (2005) points out that sea level measurements show that the highest levels during the year are presented in Coatzacoalcos (189 to 213 cm), while in winter in Ciudad Madero it reaches 179.8 cm and in Progress 112.7 cm. The coasts - low, sandy, with extensive adjacent wetlands, less than one meter above sea level - represent the fraction of Veracruz territory most vulnerable to sea level rise, which will affect towns and ecosystems, as well as saltwater infiltration to the groundwaters.

Important changes are likely to occur in the sea-land interface and in mangroves and coral reefs, which may be affected by the increase in sea level predicted by global warming models.

Tropical evergreen and deciduous forests are expected to have an extension in the prevalence of favorable conditions in the 2020s, to give rise to conditions that will favor the tropical deciduous forest in the 50-year horizon. It has been recognized that the Mesophilic Mountain Forests (BMM) of Mexico will be more sensitive to the increase in temperature, that is, they will be drier and warmer; They are also plant associations that are in continuous disturbance caused by natural and anthropogenic agents. This scenario for the BMM would cause dramatic changes in its structure, composition and distribution.

On the other hand, habitat destruction is the most important factor in the loss of biodiversity in Veracruz. Mammals will probably move to the upper parts of the state. Amphibians and reptiles seem to be at a disadvantage to face global warming in the Veracruz scenario (Benitez et al., 2008)

The agricultural vocation of Veracruz will result with significant effects, for example in the case of orange, the tendency is towards the decrease of the aptitude of the crop in all the hydrological regions in all the scenarios; It also emphasizes that this behavior is generally due to the decrease in winter precipitation, rather than to temperature variations (Ochoa, 2010). In general, a decrease in winter precipitation causes a decrease in fruiting and low yields. Climate change is expected to affect agricultural production (Conde et al., 2010), hydrological balances and supply (Pereyra et al., 2008), as well as the supply of inputs, the main livestock losses were concentrated in the field of animals and pastures (Salazar et al., 2008); In the southern zone, in addition to these effects, infrastructure damage is considered significant.

Predictably, the population's energy requirements will increase as climate change increases. The most striking increases per user will occur in the coastal areas: 10.3%, 20.0% and 43.4% corresponding to the periods 2020, 2050 and 2080. In sum, by the 2020s, domestic electricity consumption will increase by 35%: 7% due to population growth and 28% to climate change. By 2050 the population will contribute 62% and 65% due to climate change (for a total increase of 127% compared to the present) (Tejeda et al., 2008)

Human health can be affected in a variety of ways by climate and its variations: especially, certain vector-borne, infectious and parasitic diseases, and those associated with extreme weather events, will become more acute or more frequent as a result of climate change. Dengue may be one of the most sensitive diseases to long-term climate change (Lozano et al., 2012).

According to climate change experts, developing countries have a reduced adaptive capacity in relation to the effects of the increase in long-term temperature, this is due to a series of related factors, among which are low levels of economic wealth; the lack of physical and social infrastructure, especially in health and education; the lack of technology; the low level of efficiency and trust in the institutions and services they provide to society; the lack of information and knowledge, and finally the social inequality and poverty that prevents equity in the distribution of social benefits. For this reason, one of the objectives of poor countries must necessarily be to increase economic development, which will increase the adaptability of the inhabitants of the communities and make them less vulnerable to climate change (Guadarrama and Welsh, 2009).

Inventory of Emissions

An inventory of emissions that identifies and quantifies the main sources and sinks of greenhouse gases in a specific region is essential for any study on climate change, and in particular for the construction of measures that contribute directly to mitigating it.

In Veracruz, two inventories have been made, one sponsored by the PVCC and the second by the Climate Change Studies Program of the University of Veracruz, the first from 2000 to 2005 and the second used the previous base and was built in 2008, unfortunately not in all sectors due to the zero quality of the information required.

The concentration of Greenhouse Gases (GHG) in Veracruz has increased between 1990 and 2005 by about 300%. Estimated emissions of carbon dioxide equivalents represent about 5% reported in the national inventory for 2002 (from energy generation, agriculture and livestock).

In Veracruz on average (2000-2008 period) for the concept of solid waste disposal, agricultural production, land use change, fossil fuel consumption and oil and natural gas production, 44,736 Gg of CO2 equivalent are generated. The year 2001 and 2008 were the years in which lower and higher equivalent CO2 emissions were produced, with 39,427 Gg (11.56% of the national total reported) and 5.1978 Gg (13% of the national total reported) respectively.

Particularly, the sectors that contribute most to the total annual GHG generation are, in descending order, fossil fuel consumption, livestock production and oil and gas industry. The latter presents a notable increase in its contribution to total GHG emissions, each year from 2004 presents a considerable increase compared to the rate of increase of the other sectors.

Regarding the waste disposal sector, there is a notable increase in CO2 emissions equivalent, for the period 1998-2008 of 29%. Emissions from uncontrolled sites are greater than those from landfills, although the latter have increased during this period, from 10% to more than 40% of the total.

The preliminary inventory 2000-2004, product of the Veracruz Climate Action Plan, is the only study directly referred to in the Veracruz Development Plan 2011-2016, the results can be the basis for GHG emission mitigation scenarios, which represents a development opportunity as indicated by the PICC given the economic diversity of the state and the demand for energy, however, public management and mitigation policies for the state of Veracruz are necessary. The latter could be considered as a necessary and non-optional measure within a few years, especially when there is a Climate Change Law in Veracruz that omits what is mentioned in the PVD 2011-2016.

Public policies and climate change in Veracruz

The competences in environmental matters are a complex element, in the particular case of Mexico these competences reside in three different orders - national, state or local - and sometimes depending on the subject in question it is possible that these orders share actions (García and Welsh, 2011).

Development Plans are a tool, a guide where the strategy and vision of the future is expressed in some detail, which implies a political commitment to attend through concrete actions, establishing a series of strategies to achieve the goals or objectives set, in that sense each incoming government has the obligation, regardless of whether it is local, state or federal to build or develop in a systemic way a plan that harmonizes the vision of the future with the current commitments facing society, business and government management, axis on which public policy is based on.

In this sense, the 2011-2016 Government of the State of Veracruz developed a comprehensive development plan with an inclusive political vision and with clear objectives.

"The Veracruz Development Plan structures long-term strategies with a vision that highlights the attention to social development policies based on participation; it encourages the increase of income to reflect it in the internal product and the creation of jobs; it strengthens institutions, both of the State and of society, to encourage democratic options and the strengthening of citizens. These three strategies give rise to the four axes of Government on which the Plan is based:

1. Build the present for a better future for all
2. Strong economy for people's progress
3. Consolidate a sustainable Veracruz
4. Develop an efficient and transparent government and administration" (PVD, 2011)

For all the above, in the axis number 3 the results of the preliminary inventory of greenhouse gases of Veracruz, developed by the global exchange group of the Center for Earth Sciences of the University of Veracruz, which is part of a broader study - about 20 studies - that gave meaning to the Veracruz Program on Climate Change (PVCC).

As a temporary breviary, it is convenient to point out that the Governments of Veracruz have always had an environmental sensitivity and commitment, in Veracruz the first Law on environmental protection was developed in the 1970s, while in 2007 the issue of Climate change appeared in official speeches, as a cause of floods and the increase in extreme events in the Gulf of Mexico, the head of the executive branch, governor in turn of Veracruz, attended various forums to listen to experts speak on the subject and as a consequence of the actions before this global phenomenon, he took local actions, for example: the Center for Climate Studies was founded in the Ministry of Civil Protection, with the support of the University of Veracruz, he built his organization chart; During the same six-year period, an initiative for the creation of the undersecretary of environment and climate change in the Ministry of Social Development and Environment was presented in 2010 and during the same year the initiative of a law on mitigation and adaptation to climate change was presented to the Congress of the State, which was discussed in a public forum with the academy, a pioneer in the country that was approved by the legislature in the last sessions of the administration.

Mitigation as part of the PVD and in the context of the law

The impact of applied research in the social field is to become public policy, or at least contribute to the construction of it, so that this is possible three actors are needed: the academy as a generator of knowledge, which is responsible for communicating efficiently its results; the government as a generator of political consensus, which in turn allows the development of laws and regulations with solid, real and applicable bases with social meaning and relevance; and finally the organized and unorganized civil society, which will be responsible for subduing the applicability of the norm and pointing out the inconsistencies of its application.

Mitigation in the PVD

Chapter V, A Sustainable Veracruz, describes the environmental situation that Veracruz saves, there appears for the first time in the discourse of the PVD the concept of mitigation as one of the six priority axes or challenges of the environmental agenda, it is It is possible to assume that they are not ordered by importance, since all as a whole are necessary for the conservation of the natural capital of Veracruz.

It is pertinent to note that the concept of mitigation is used in various fields as a synonym for reduction, especially when talking about risk, but in the PVD as it is done in the PICC evaluation reports it is used to indicate the reduction of GHG .

Likewise, it specifically states that it promotes and strengthens development policies that integrate the environmental component between the three orders of government, the academy and the private sector, this is a challenge that is articulated in the discourse, but applied in mitigation to climate change, the fourth objective says:
"IV. Mitigate greenhouse gas emissions and carry out climate change adaptation actions to reduce the vulnerability of the population and ecosystems ”(PVD, 2011).

In turn, he mentions that if he does not undertake actions to mitigate climate change, the alterations will be irreversible, until life is endangered on the planet, it is important to envision a component of intra- and inter-generational responsibility as part of the structure of the PVD. On the other hand, developing countries - such as Mexico - are part of the so-called ANNEX I by the PICC, are countries that do not have the responsibility of a mitigation policy, and Veracruz with a contribution slightly below 4% National is truthfully involved in actions to face humanity's biggest challenge in the last 100 years: climate change.

> *“Climate change requires designing and adapting public policies and actions that promote inter-institutional and intersectoral coordination, and involve the public and private sectors ...”*

The previous declaration of intention was the one that gave foundation to Veracruz’ Plan before the Climate Change and caused that the impact of the results of the preliminary inventory of greenhouse gas emissions was the basis of the construction of reduction goals and the construction of the Law.

For all the aforementioned, the PVD indicates as strategies in the field of climate change: Promote the application of the State Law of Mitigation and Adaptation to the Effects of Climate Change; Develop and coordinate the State Strategy for Mitigation and Adaptation to the Effects of Climate Change (indicated in the Law); and finally Promote and promote the coordinated management of GHG reduction actions.

Mitigation in Law 878 of Veracruz

The Climate Change Mitigation and Adaptation Act initiative was presented by the executive branch of the Government of Veracruz to the H. Legislature, the legislature held a consultation forum with the academy, where some experts on climate change and academics with specialties participated far from the subject, resulting in a debate that failed to influence substantial modifications to the initiative before its approval.

State Law 878 on Mitigation and Adaptation to the Effects of Climate Change was approved and published in the official body on November 3, 2010, less than 30 days after the entry of a new State Government; This Law was the first one that was approved at national level and is oriented with greater emphasis towards mitigation than to adaptation, a situation that is indicated by a group of academics who in a letter sent to the legislature express:

> *"This bill focuses on the mitigation of greenhouse gas emissions and adaptation is mentioned tangentially, when Veracruz is one of the most vulnerable states to extreme hydro-meteorological phenomena: floods, frost, droughts, heat waves and cold waves, to name a few. That is to say, the aforementioned Climate Change and Change of Government ... and PVCC, in which the adaptation and mitigation are balanced in a balanced way, should be considered as an obligatory reference."* (Letter sent to the H. Legislature of Veracruz dated September 9, 2010 by the Coordinator of the PVCC).

It should be noted that article 7 of this law describes five guidelines, 66% of which are indicated and made clear in the PVCC, as a result of the actions indicated for the reduction of GHG, which mentions:

> *"Article 7. Regarding the mitigation of greenhouse gases, the following guidelines should be considered:*
> *I. The preservation and increase of carbon sinks;*
> *II. In urban centers with more than fifty thousand inhabitants, the systematization of solid waste management so that they do not generate methane emissions;*
> *III. In all urban centers, public transport units must meet emission standards, subject to vehicle verification programs or concessionaires may opt for other more efficient collective transport systems; and*
> *IV. The State, in accordance with the federal regulations of the matter, will seek the generation of electrical energy for its facilities, with the use of non-polluting sources, such as wind, sunlight, biomass, sea waves..."*

It should be noted that these guidelines nuanced in the PVCC were described with the responsible actors, responsible for their implementation and with the added value of an analysis of the budget necessary for its implementation, this kind of design implied a reallocation of the regular budget of the State of Veracruz did not mean new public spending, nor the need to generate public debt for its implementation. However, despite the clarity with which it appears in the law and the precision with which the PVCC was built, in particular that related to mitigation, elections and the change of government in Veracruz buried the Law, the results of the PVCC and So far, its application has not been possible in such a way that it is possible to ensure that the research applied in the field of climate change mitigation has managed to become a real public policy, for now and unfortunately it is only de facto.

Methodological calculation proposal

The most authoritative methodology worldwide for the estimation of greenhouse gas (GHG) emissions is that described in the IPCC Guidelines for National Inventories of Greenhouse

Gases, revised 1996 version (IPCC 1996). The IPCC, as mentioned above, is a group of experts on Climate Change.

Hundreds of the world's leading experts participate in the IPCC to examine the most up-to-date and peer-reviewed literature on the scientific and technical aspects of climate change. Its tools, such as the IPCC guidelines, are fully endorsed internationally. Even Mexico, like many other countries estimate their GHG emissions nationwide by applying the methods set out in the IPCC guidelines.

The IPCC guidelines consist of 3 volumes:

• Instructions for the presentation of reports of the National Inventory of Greenhouse Gases (Volume 1).

• Workbook of the National Inventory of Greenhouse Gases (Volume 2) (IPCC 1996a).

• Reference Manual of the National Inventory of Greenhouse Gases (Volume 3). (IPCC 1996b).

These 3 volumes present the suggested methodologies for the estimation of atmospheric pollutants such as carbon dioxide, methane, nitrous oxide, carbon monoxide, nitrogen oxides, volatile organic compounds other than methane, halocarbons, sulfur hexafluoride and sulfur dioxide, from activities and sectors such as energy production, industrial processes, solvents and other products, agriculture, change in land use and forestry and waste management.

The IPCC guidelines are complemented by updated publications such as the Guide to Good Practices and Uncertainty Management in National Inventories of Greenhouse Gases, Guide to Best Practices for Land Use, Change in Land Use and Forestry and the 2003 IPCC Greenhouse Gas National Inventories Program.

The IPCC methodology for GHG estimation is divided into several levels or methods. Generally, the higher the number to designate the level, the more detailed the methodology and the more accurate the emission estimates.

Level 1 represents the minimum or default methodology. If there is enough data available you can try to apply a higher level.

Levels 2 or 3 involve more elaborate methods that can be category specific or technology based. These methods require more detailed data and / or measurements for their application.

The basic model for estimating atmospheric emissions is based on the following equation:

$E = A * FE$ (1)

Where:

A = Amount of activity from a source in question

FE = Typical emission factor of said activity (usually expressed as the weight of the contaminant between the unit of weight, volume, distance or duration of the associated activity)

E = Atmospheric emission.

The PICC guidelines offer a methodology that includes default emission factors and in some cases activity data (information from sources that give rise to GHGs) by default.
The default emission factors have been developed by the IPCC based on the following sources:

- Default Emission Factors Handbook (European Environment Agency Task Force, Bouscaren, 1992).
- CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic, Volume 1: Methodology and Emission Factors (Eggleston, et al.,1992).
- Atmospheric Emission Inventory Guidebook (Joint EMEP/CORINAIR, European Environment Agency, 1996).
- US EPA's Compilation of Air Pollutant Emissions Factors (AP-42), 4th Edition 1985, (US EPA, 1985a and 1985b), 5th Edition 1995 (US EPA, 1995) and Supplement F, (US EPA, 1993b).
- EMEP and CORINAIR Emission Factors and Species Pro les for Organic Compounds. (Veldt, 1991).
- The Emission Database for Global Atmospheric Research. (EDGAR 1995), version 2.0.

Final comments

The entire population of Veracruz knows that they live in a territory where weather conditions condition their vulnerability, drought in the north and floods in the south, the effects of climate change seem to be directly related to the adverse impacts that the population suffers year after year, Public policy in the field of civil protection takes great and safe steps, while climate change regulations sleep the dream of the righteous.

In terms of mitigation, the opportunities are wide, the spaces for action with the appropriate parastatal companies and the certainty of accessing the international mechanisms generated for the commercialization of carbon credits are being lost when the general guidelines described in the law are not They comply, where the PVD is disregarded since the direction it points out is not taken into account and relations with the academy, the private sector and the government do not end up consolidating in this area.

It is necessary, perhaps even urgently, to initiate local air pollution prevention and control tasks (there is no atmospheric monitoring data), ensure that local governments are integrated into a single emission inventory scheme, and finally that the law is complied with , just to close this text article 29 of law states:

> "*For the mitigation of the harmful effects of climate change, the prevention and control of air pollution by greenhouse gases and other particles with the same consequences, the following guidelines will be observed:*
> *I. In all human settlements, air quality will be according to official standards;*
> *II. Production and consumption patterns that reduce emissions will be promoted;*
> *III. Companies in the social and private sectors will be supported and encouraged to reduce their emissions;*
> *IV. Energy science practices will be promoted, the replacement of the use of fossil fuels by renewable sources of energy and the transfer and innovation of clean technologies;*

V. Programs to prevent deforestation and degradation of natural ecosystems will be reinforced; and VI.. It will monitor, verify and report on the mitigation actions undertaken."

References

Benitez, G. A. Hernández, M. Equihua, A. Medina, J. Álvarez, S. Ibañez, C. Delfín (2008). Biodiversity and climate change. In Studies for a Veracruz Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. chap. 4. Impacts on the natural environment.

Count, C., O. Sánchez F. Estrada, B. Martínez, F. López, M. Lozano, C. Gay. Regional Climate Change Scenarios for Mexico. Atmosphere, special number. 2010 (in press).

Garcia T. and C. Welsh (2011). Instruments for Integrated River Basin Management in Mexican Environmental Law. Journal of Political and Sociological Research. ISSN 1577-293X. Vol. 10. No. 3. pp. 131-148.

Lozano, S., C. Welsh, M. Hayden, B. Tapia, C. Ochoa, K. Kobylinski, C. Uejio, E. Zielinski, L. Delle, A. Monaghan, D. Steinhoff, and L. Eisen (2010). Aedes (Ochlerotatus) epactius Along an Elevation and Climate Gradient in Veracruz and Puebla States, Mexico. Journal of Medical Entomology, 49 (6): pp. 1244-1253. 2012

Ochoa, C. (2010). Statistical Modeling of the Impact of Climate Change on Orange Production in the State of Veracruz. Thesis to obtain the degree of M. in E., University of Veracruz. 170 pp.

Palma, B., C. Conde, R. Morales, G. Colorado (2008). Climatic scenarios. In Studies for a Veracruz Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. chap. 3. Climate modeling and statistical evidence.

Palma, R., (2008). Vulnerability of the coasts: notes for a general characterization. In Studies for a Veracruz Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. chap. 4. Impacts on the natural environment.

Pereyra, D., J. Pérez, A. Contreras. (2008). Future scenarios of water resources. In Studies for a Veracruz Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. chap. 4. Impacts on the natural environment.

Salazar, S., A. Hernández, S. Muñoz, B. Dominguez, P. Cervantes, C. Lamothe. (2008). Cattle raising: vulnerability and mitigation. In Studies for a Veracruz Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. chap. 5. Economic aspects.

Tejeda, A., G. García (2008). Scenarios of electrical consumption by air conditioning. In Studies for a Veracruz Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. chap. 5. Economic aspects

PVCC (2008). Veracruz' Program to Climate Change. University of Veracruz, National Institute of Ecology and British Embassy in Mexico. 169 pp.

PVD (2011). Veracruz' Development Program 2011-2016. Government of the State of Veracruz. 156 pp.

Chapter 9

Institutions and instruments of the European Union in the fight against climate change

Edgar Saucedo Acosta
Samantha Rullán Rosanis

Abstract

In recent years, the European Union (EU) has made efforts to assume the role of world leader in the fight against climate change. To achieve this goal, the EU has institutions and instruments. This chapter presents the strategies and programs used by European institutions to fight against climate change. In particular, the Europe 2020 Strategy, which takes into account the EU leadership around the Kyoto Protocol, establishes quantifiable targets for greenhouse gas reductions by 2020, and the flagship initiative "A Europe that effectively uses resources" which is a roadmap of how to reach the goals for 2020 and 2050. Finally, the EU Budget reflects the concern of Member States regarding the fight against climate change, in addition to the fact that such policy is becoming increasingly a transversal, because it has been incorporated into other European public policies.
Keywords: European Union, climate change, institutions, instruments, Europe 2020.

The European Union and the fight against climate change

In the founding treaties of the EU the environment did not appear. The first directives on the environment were adopted at the end of the 1960s. In 1972, we began to talk about a common environmental policy. Subsequently, the legal basis of the common policy is included, in 1987, in the Single European Act and then in the Maastricht Treaty.

The European strategy to combat climate change is developed in four different areas:

1. Climate risk and the political will to deal with it.
2. International participation in the fight against climate change.
3. The innovation necessary for a change in methods of production and use of energy.
4. Adaptation of countries to the inevitable effects of climate change.

At European level, among the emerging climate-related initiatives is the first community strategy to limit carbon dioxide emissions by improving energy efficiency in 1991. Subsequently, EU policies and measures to reduce emissions from the greenhouse effect was embodied by the European Commission in the European Climate Change Program (PECC) launched in June 2000. The general objective of the PECC is to "determine and develop all the elements of the European strategy to deal with climate change that are necessary to implement the Kyoto Protocol" (European Commission, 2000). The proposals for common and coordinated climate change policies and measures focused on: energy supply, industrial sector, energy consumption in the residential and tertiary sectors, energy consumption in the transport sector, transport and infrastructure policy, waste, research and international cooperation.

Five years later, the PECC II (2005-2010) was launched, based on incorporating new European policies and cost-effective measures to reduce greenhouse gas emissions in synergy with the Lisbon Strategy (EL). The first assignment in this phase was to facilitate and support the implementation of the priorities that were identified in the first phase. One of the most important actions to combat climate change, within the framework of the PECC, is the EU regime for the trading of greenhouse gas emission rights (ETS) that began in January 2005.

The ETS is an international carbon dioxide emissions trading system that became a promoter of carbon trading in the world. The operation of this system is to apply a cost to the carbon emissions of the facilities of the energy and industrial sectors to encourage companies to minimize their emissions as much as possible. Each facility has a specific number of emission rights granted by the national authorities of each EU member country. On the one hand, if the company keeps its emissions below the level of its rights, it can sell them to other companies. On the other hand, if the company exceeds the limit or limit of rights granted, it has the option of buying in the market the additional rights it needs.

The fight against EU climate change abroad is regulated in Article 191.1 of the Treaty on the Functioning of the EU, which establishes as an objective of external action "the promotion of measures at international level aimed at addressing the problems regional or global environment and in particular to fight against climate change ". At the multilateral level, the EU has actively participated in actions against climate change. Obviously, one of the most important international legal instruments to fight against climate change is the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Industrialized countries pledged to limit and reduce their emissions. In 1998, the European Commission signed the Protocol and three years later, at the Laeken European Council, it confirmed the EU's willingness to enter into force before the Johannesburg sustainable development summit in 2002. In May 2002 , the EU ratified the Kyoto Protocol. Thereafter, the EU began to reduce its greenhouse gas emissions and it was necessary to develop its medium and long-term strategies to combat climate change.

In the Communication "Winning the battle against global climate change" (European Commission, 2005), the European Commission laid the foundations for the future EU strategy on climate change and proposed concrete recommendations for EU policies in this scope that includes the following elements:

1. Enlargement of participation: The EU will continue to play a leading role in the multilateral approach to climate change and more countries need to take effective measures to reduce emissions and reduce negative economic impacts.

2. Inclusion of more political areas: expand the scope of international measures to include all sectors and greenhouse gases. Specifically address the problem of greenhouse gases in certain regions due to the change in land use.
3. Empowerment of innovation: develop a technology policy that encourages innovation to develop new low emission technologies (achieve energy efficiency and develop low carbon energy sources) and bring them closer to the market.
4. Permanent use of flexible and market-based instruments: emissions trading and project-based mechanisms as basic elements of an authentic international carbon market, emission control and notification standards and a multilateral compliance regime. Motivate more countries to participate in the fight against climate change.
5. Inclusion of adaptation policies: allocate more resources in the EU for processes of effective adaptation to climate change. In addition, financially support the adaptation efforts of the poorest and most affected countries.

Two years later, in 2007, the European Commission proposed more specific actions to minimize the effects of climate change. He proposed that the EU promote reducing greenhouse gas emissions by 20%[11] in developed countries from that moment until 2020 to limit the rise in global temperatures. In addition, it notes that instruments such as the emission rights trading market are essential to achieve the stated objectives.

Borrás (2009) makes a deep criticism of the EU leadership in multilateral negotiations to combat climate change and affirms that "the traditional leadership of the EU in the fight against climate change has been based on an analysis of threats and opportunities and cost / benefit, considering that the current fight against climate change is much more beneficial than addressing its consequences and the number of threats affecting European interests. " He also points out that the EU lost the opportunity to demonstrate its leadership at the Copenhagen Summit.

The Copenhagen resolutions did not meet the expectations of the European institutions. The result of the failure of the negotiations was reflected in the fact that a legally binding climate agreement was not concluded. Subsequently, the European Commission in a Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (European Commission, 2010a) proposes an immediate strategy to maintain the momentum of global efforts in the global fight against climate change.

The European Commission states that the demonstration that EU Member States are implementing the Copenhagen Accord is an important element in persuading other global actors to join actions against climate change. To achieve its primary objective of achieving a solid and legally binding agreement under the United Nations Framework Convention on Climate Change (UNFCCC), the Commission proposed to focus on the adoption of concrete and decisive decisions at the Cancun Summit on Change Climate (2010). At the multilateral level, the EU continues to make efforts to convince other countries to join and commit to continue fighting against climate change.

[1] Regarding the 1990 levels.

European institutions and organizations in the fight against climate change

The role of European institutions is essential in the fight against climate change. Among the institutions and agencies that carry out specific work in this area are: the European Commission, the EU Council, the Parliament, the European Council and the European Environment Agency (EEA). Below are some of the actions and strategies to fight against climate change in European institutions and organizations.

In 1990, the EEA was created based in Copenhagen. It is an EU body and its job is to provide the EU and its Member States with solid and independent information about the environment. The EEA analyzes the state of the environment and its trends, the development of scenarios and the evaluation of policies, among others. It is one of the community agencies created to perform specific technical, scientific or management tasks. The EEA has 32[2] Member States and 7[3] collaborating countries. Among its responsibilities is to develop the European Network for environmental information and observation (Eionet) and coordinate its activities.

The European Commission established the Directorate General for Climate Action ("DG CLIMATE") in February 2010. Previously, climate change was included in the Directorate General for the Environment. DG CLIMATE develops and implements national and international cost / effective policies and strategies to achieve the proposed objectives for 2020 of the EU, especially as regards reducing greenhouse gases. He leads the working groups in international negotiations and coordinates bilateral and multilateral climate change partnerships with third countries.

DG CLIMATE develops and implements the emission rights trading regime, considered as the cornerstone of the EU strategy to profitably reduce its greenhouse gas emissions. In addition, it monitors the implementation, of the EU Member States, of the emission reduction objectives of sectors not included in the ETS.

Within the formations of the Council of the EU is the Environment. Its mission is to promote a harmonious, balanced and sustainable development of economic activities. In addition, it encourages at international level the adoption of measures aimed at addressing regional and global environmental problems. Community environmental policy is based on the principles of caution and preventive action, the correction of attacks on the environment, primarily at the source, and on the principle that the polluter pays.

In the European Parliament, the fight against climate change is an essential part of the work of the Committee on the Environment, Public Health and Food Safety (ENVI). This Commission is competent for the strategy regarding climate change, the EEA and the repair of environmental damage, among others.

[2] There are the 27 Member States of the European Union, Iceland, Liechtenstein, Norway, Switzerland and Turkey.
[3] Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia and Kosovo.

In the conclusions of the European Council of 1 and 2 March 2012, with regard to the Europe 2020 strategy, it states that its objectives remain fully relevant. This strategy will continue to guide the actions of the Member States and the EU to achieve energy and climate change objectives. In addition, for the G20 summit, it agreed to give priority to the fight against climate change in particular and to mobilize sources of financing for measures to combat climate change, among others. While European institutions and organizations promote actions and strategies in the fight against climate change, in the Member States the disparity in the objectives set in this area is evident (see Table I).

Europe 2020 strategy and climate change

The European Strategy 2020 (E2020) was approved by the European Council in June 2010 and replaces the EL launched in the year 2000 and subsequently re-launched in 2005, after a review of it carried out by a high-level group headed by the former Prime Minister of the Netherlands, Win Kok. Before going into detail to analyze the E2020 Strategy, it is worth noting that the EL was looking for the EU in 2010 to become "the economy based on the most competitive and dynamic knowledge of the world, capable of growing economically in a sustainable way with more and better jobs and with greater social cohesion "(European Commission, 2004). However, with the financial crisis of 2008-2009, the parameters that had been raised in the EL were no longer feasible. The E2020 Strategy takes up the essence of EL and converts it into specific objectives that must be achieved at European level, but there are also quantitative goals that Member States have to obtain.

E2020 is an EU strategy to generate intelligent, sustainable and inclusive growth over the next decade (European Commission, 2010b), which basically refers to generating the necessary jobs in an environment of high productivity and social cohesion. The above priorities translate into quantifiable objectives for the EU on average and specifically for its Member States.

The environmental objectives of the E2020 Strategy for the year 2020 are (European Commission, 2010b):

1. A 20% reduction in greenhouse gas emissions compared to 1990. In the event that conditions exist, this goal is extended to 30%.
2. A 20% increase in the use of renewable energy.
3. A 20% increase in energy science.

Table I shows that the European average differs in terms of reduction of carbon dioxide emissions and use of renewable energy in relation to what Member States have to achieve by 2020. The EU's goal is to reduce emissions from carbon dioxide by 20%, but there are countries like Bulgaria, the Czech Republic, Estonia, Lithuania, Latvia, Malta, Poland, Portugal, Romania and Slovakia that can still increase their emissions, while countries like Denmark, Ireland and Luxembourg have to reduce a percentage similar to that of the EU. In terms of the use of renewable energy, the difference between the objectives of the EU and the Member States is very marked, because there are countries like Sweden that have set the goal of using 49% of renewable energy from their total energy consumption, while countries like Malta only target 10%. The implications of these differences are related to the different efforts that countries have to make, and even more so in an economic crisis scenario like the one the EU is experiencing. The effort that countries need to make is focused on generating incentives for the use of clean energy, as well as a strong investment in eco-innovation.

Figure 1 shows the progress of the EU in reducing greenhouse gas emissions, due to the general decline from 1990 to 2010. However, the period where it is most marked is between 1990 and 1994, after which It gives a stagnation in the period 1994-2006 and subsequently an improvement until 2009 that was interrupted in 2010, due to the economic crisis that has affected Europe. Everything seems to indicate that the goal of a 20% reduction is very likely to be achieved by 2020.

Table I. Climate change and energy: Objectives by country.

País	Reducción de emisiones de CO2 (%)	Energías renovables (% del total)
UE	-20%	20%
Austria	-16%	34%
Bélgica	-15%	13%
Bulgaria	20%	16%
Chipre	-5%	13%
Rep. Checa	9%	13%
Alemania	-14%	18%
Dinamarca	-20%	30%
Estonia	11%	25%
Grecia	-4%	18%
España	-10%	20%
Finlandia	-16%	38%
Francia	-14%	23%
Hungría	-10%	14.65%
Irlanda	-20%	16%
Italia	-13%	17%
Lituania	15%	23%
Luxemburgo	-20%	11%
Letonia	17%	40%
Malta	5%	10%
Países Bajos	-16%	14%
Polonia	14%	15.48%
Portugal	1%	31%
Rumanía	19%	38%
Suecia	-17%	49%
Eslovenia	4%	25%
Eslovaquia	13%	14%
Reino Unido	-16%	15%

Source: *http://ec.europa.eu/europe2020/pdf/targets_es.pdf* (Retrieved September 26th, 2012)

Figure 1. Greenhouse gas emissions in the EU (in CO2 equivalent).
Source: Based on data from the European Environment Agency.

Figure 2 shows that there are countries that are far removed from the EU objective of a 20% reduction in greenhouse gases (80% in the figure). However, just as national objectives differ from the EU average, national efforts also vary. For example, even though Cyprus has increased its emissions by more than 60% since 1990, it aims to reduce 5% compared to 1990, while Malta can even increase up to 5% more. Countries that currently go through strong economic problems such as Spain, Greece, Ireland and Portugal have indicators above 100%, and will have to make great efforts to achieve their national objectives.

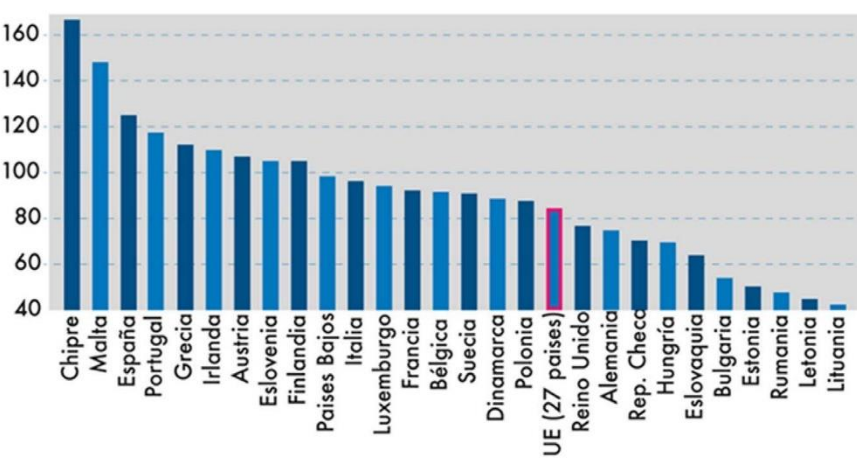


Figure 2. Emissions of greenhouse gases in 2010 (equivalent CO2. Source: Based on data from the European Environment Agency.

The little progress in the use of alternative energy in the EU can be seen in Figure 3. The objective is to reach 20% of use of alternative energy in the EU by 2020, but in this figure, there is only an advance of 8% in 2004 to a little more than 12% in 2010. There are still 10 years to reach the final goal, but the current economic crisis can delay obtaining it.

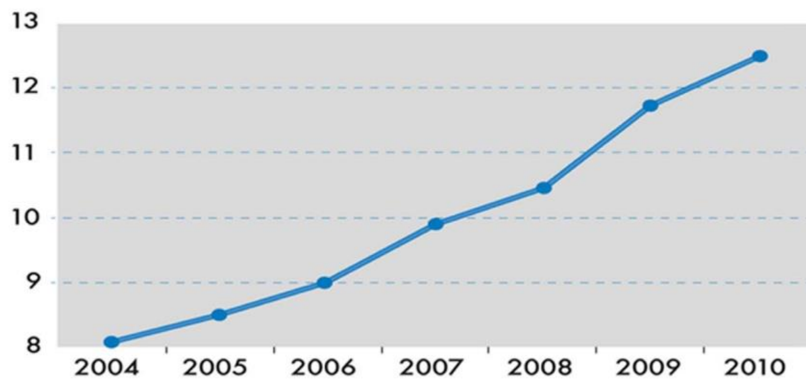


Figure 3. Percentage of renewable energy in the final energy consumption in the EU. Source: Based on data from Eurostat.

Figure 4 shows the difference between what EU Member States use of renewable energy (of total energy consumption) and the goal they have to reach by 2020. Sweden is an extreme case, because it has a 2020 goal of using almost 50% in renewable energy, but by 2010 it already uses more than 45%. Romania is the EU country that least lacks to achieve its national objective, followed by Estonia, Sweden, Bulgaria and Lithuania. On the other hand, the countries that are farther from reaching their national goal are the United Kingdom, Ireland, the Netherlands, France, Malta and Cyprus.

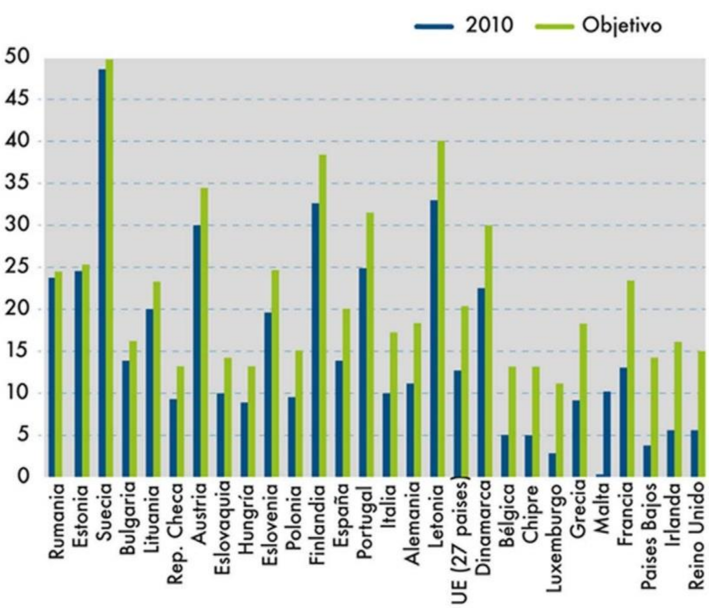


Figure 4. Percentage of renewable energy in gross annual consumption of energy by country. Source: Based on data from Eurostat.

For the implementation of Strategy E2020, seven flagship initiatives were established, of which only one is directly related to environmental issues. It is clear that the other six indirectly relate in some way to the environmental part of the E2020 Strategy, but the objective of the text will only deepen the fourth flagship initiative "A Europe that effectively uses resources."

With the passage of time more resources will be required to meet the needs of a larger population at European level but also in the world, therefore it is necessary to make more efficient use of resources. To make more efficient use of resources, it can be done through a reduction in the inputs needed to produce a product or by increasing productivity in companies and in general in the economy of the countries. A more efficient use of resources increases competitiveness, reduces costs and therefore generates jobs and economic growth. The flagship initiative “a Europe that effectively uses resources” starts from the above to encourage a more appropriate use of natural resources, through the optimization of inputs that allow at the same time a cost reduction (increasing competitiveness) and a reduction of environmental impacts. The idea is that European economies have a low consumption of coal, which will achieve the objectives of a reduction of greenhouse gas emissions by 2020 (20%) and 2050 (80-95%).

The European Commission (2011c) recognizes that in order for the flagship initiative “a Europe that effectively uses resources” to contribute to the E2020 Strategy, three conditions must be met:

1. Coordination: different public policies must be coordinated so that this emblematic initiative can be implemented.
2. Long-term investments: action must be taken immediately because there are investments that have long-term impacts.
3. Empower consumers: consumers should be empowered to use products that are produced efficiently (in ecological terms).

A fourth condition would be added, promoting eco-innovation (mainly through public investment) as a mechanism that favors products or processes that are increasingly friendly to the environment.

The flagship initiative "A Europe that effectively uses resources" recognizes that a necessary condition is to ensure investment certainty and innovation in the long term. This initiative provides a long-term framework in areas such as “climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity and regional development” (European Commission, 2011c). In the long term it is established in coordinated roadmaps to achieve the objectives in 2050: reduction of 80-95% of greenhouse gases, generate an energy system of coal consumption that certifies all the actors involved, eliminate all obstacles in the internal market for the use of clean technologies and the modernization of transport networks (European Commission, 2011a).

The European Commission has drawn up a roadmap that the EU has to follow, so that by 2050 it has a competitive economy with low carbon use (80% reduction in greenhouse gas emissions in relation to 1990). Figure 5 shows the current scenario (red line) if they continue to apply the same public policies, where it is clearly seen that the 2020 target will be achieved, but for the 2050 one a gap is opened. This is because the objectives of using alternative energy and energy efficiency by 2020 are far from being achieved.

To reach the 2050 goal, the greatest reductions would be in the electricity, industry and transport sector and to a lesser extent in agriculture, the residential sector and other sectors. The change to a low-consumption economy for the EU implies the use of clean technologies, as well as an improvement in energy efficiency that require large public and private investments to generate eco-innovation.

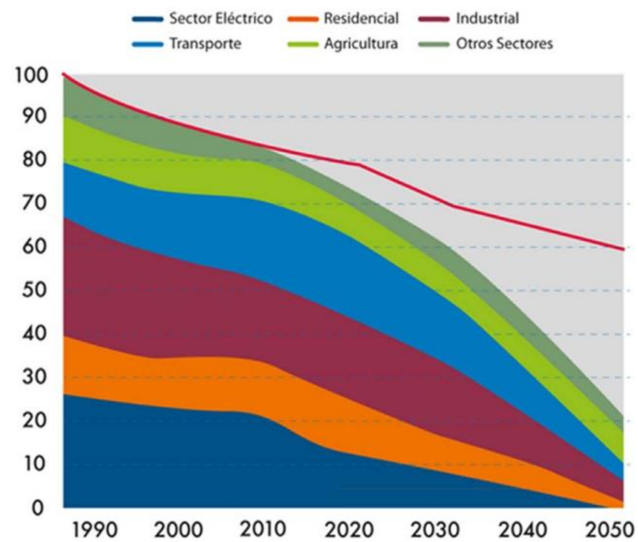


Figure 5. Emissions of greenhouse gases from the EU towards an 80% reduction. Source: Based on data from the European Commission (2011a).

The 2020 measures (medium term) of this flagship initiative (European Commission, 2011c) are: an energy efficiency plan, which takes into account in the budget of several European policies the requirements for the European economy to have low consumption coal, a new biodiversity strategy, the definition of a commercial policy that supports a (sustainable) supply of raw materials in global markets, improve the recycling system, minimize the effects of climate change and a savings policy and efficiency in the use of water.

The flagship initiative "a Europe that effectively uses resources" points out that in environmental issues there must be joint action at international level, due to externalities generated by environmental public policies (or the absence of them). Finally, there is a follow-up to the goals that were set for this flagship initiative, which go hand in hand with the quantitative goals of the E2020 Strategy.

Budget proposal of the European Commission for 2014-2020 and climate change

The Multiannual Financial Framework (MFF) de facto establishes priorities in community policies for the coming years and constitutes both a budgetary and political framework (European Commission, 2011b). Every year budgets are made that must respect the limits established by the MFP for community policies and their financing, in order to ensure predictability in spending. The 2014-2020 MFP establishes a 1.05% (average) ceiling for budget revenues in relation to the Gross Domestic Product of the EU economy. Total expenses for this period have been established at 972,980 million euros, spread over the seven years (European Commission, 2011b). The community policies that will receive the most money in the 2014-2020 period are Smart and Integrative Growth (48%) and Sustainable Development (37%), while the rest will collectively receive 15% of the budgets.

In relation to the environment and climate change, the MFF 2014-2020 sets the following goals:

1. Payments conditional on farmers: 30% of the direct payments of the Common Agricultural Policy are conditioned on farmers making environmentally friendly practices.
2. Transversality of environmental policies in the budget: environmental policy and the fight against climate change will be integrated into the costs of Cohesion, Agriculture, Fisheries and Maritime Policy, Research and Innovation and Foreign Aid policies. The objective is that the general expenditure for the fight against climate change corresponds to 20% of the total budget.

To achieve the objectives of reducing greenhouse gas emissions and improving the environment, the EU Budget has the following instruments (European Commission, 2011d):

1. Cohesion policy will be conditioned to contribute to the EU climate change objectives.
2. Through the Common Strategic Framework for Innovation and Research, actions with positive impact on climate change will be supported in areas such as transport, energy, research materials and sustainable bio-economy.
3. The rural development policy will focus on encouraging farmers to have an environment friendly environment.
4. The Integrated Maritime Policy will be responsible for defining the sustainable borders of human activities that have an impact on the maritime environment.
5. The External Action Policy will focus on supporting candidate countries in environmental issues, so that they adapt their environmental regulations and practices to community acquisitions.

The LIFE+ program will continue, which basically consists of support from the European Commission for research projects that seek conservation and sustainable development. The LIFE + program will support measures against climate change for regional and local projects, in addition to support for Small and Medium Enterprises (SMEs) that test small-scale low-carbon technologies. A total of 800 million euros for the 2014-2020 period (European Commission, 2011e) is budgeted for the LIFE+ program (climate sub-program). The LIFE + sub-program of the environment has the following priorities: LIFE Biodiversity that focuses on best practices in relation to biodiversity, LIFE Environment that will focus on the implementation of legislation that is consistent with Strategy E2020 and LIFE Governance consisting of networking for the exchange of best practices that go hand in hand with the EU's environmental policy priorities. The LIFE + environment subprogram has a fund of 2.4 billion euros for the 2014-2020 period (European Commission, 2011e).

Final considerations

The EU has been a leader in the International Forums on climate change. Even if you do not always achieve the objectives that you set, continue developing your strategy to obtain them. In addition to that it has implemented a series of policies aimed at meeting the objectives of the Kyoto Protocol. The way in which the EU is composed means that many of its public policies, including the fight against change, are the product of the negotiations that Member States have on the subject in question, so that the final product reflects the sum of preferences

At present, the issue of climate change is of utmost importance for the EU and its Member States, in addition to being present in the implementation of other public policies. The E2020 Strategy reflects the concerns of European countries in the fight against climate change, especially setting quantifiable objectives for the year 2020 that are likely to be evaluated year after year. In addition, an emblematic initiative related to climate change has been established, which basically consists of a road map to achieve the proposed objectives. Additionally, objectives for 2050 have been established that allow the EU to have a longer-term horizon.

The EU budget reflects, in a certain way, the concern of its Member States to achieve the climate change objectives in 2020. Each year, what goes into the fight against climate change grows, not only in monetary amounts, but also as a requirement so that money is granted in other public policies. The European institutions have tried to turn the fight against climate change into a transversal policy, that is, that the reduction of greenhouse gases have an impact on several European public policies. The European experience in this area is extensive and the exchange of good practices of great use for regions and countries that wish to join these efforts.

References

Borrás, S., 2009. Climate security in the European Union: between threats and opportunities. Catalan magazine of public dret, No. 38, pp. 273-304.

European Commission, 2000. Communication from the Commission to the Council and the European Parliament on EU policies and measures to reduce greenhouse gas emissions: towards a European Climate Change Program (PECC). European Communities, Brussels, 14 pp.

_____, European, Grupo de Alto Nivel, 2004. Facing the Challenge: The Lisbon strategy for growth and employment. Comunidades Europeas, Bruselas, 55 pp.

_____, European, 2005. Communication: Win the battle against global climate change. European Communities, Brussels, 19 pp.

_____, European, 2007. Communication: Limit global warming to 2 –C - Measures needed until 2020 and after. European Communities Brussels, 14 pp.

______, European, 2010a. Communication: Post-Copenhagen international climate policy: an immediate intervention to reactivate the global fight against climate change. European Union, Brussels, 14 pp.

Eduardo Reinoso Angulo

He earned his PhD at the Wessex Institute of Technology, Southampton, England. He is a member of the Mexican Societies of Seismic Engineering (SMIS) and Structural (SMIE) and of the Seismic Engineering Research Institute, EERI. From 2006 to 2008 he was president of the SMIS. He has made more than 150 publications in books, congresses and technical journals. Since 1996 he is a full-time Senior Researcher at the Engineering Institute of UNAM. He is currently a Founding Partner and General Director of ERN.

Mauro Niño

Doctor of Engineering from the UNAM. He has developed several investigations oriented to the estimation of the risk by natural phenomena, participating and coordinating projects related to the definition of different dangers by geological phenomena and hydrometeorological phenomena. At the international level, he has participated in the CAPRA initiative of the World Bank, of which he has coordinated projects aimed at risk management in countries of Latin America and South Asia, such as Bhutan and Pakistan.

Ignacio Mora González

Researcher at the Engineering Institute of the UNAM and director of the Center for Earth Sciences of the University of Veracruz. He has written articles in national and international journals and is co-author of the books "Most frequent geological hazards in the state of Veracruz"; "Earthquakes, what you should know" and "Geological and Hydrometeorological Hazards in the state of Veracruz." He is a member of the Scientific Advisory Committee for Civil Protection of the state of Veracruz.

Gilbert Francisco Torres Morales

Doctor in Structural Engineering, Researcher at the Center for Earth Sciences of the University of Veracruz, Professor of the Faculty of Civil Engineering (Xalapa) of the University of Veracruz. It conducts research on the effects of earthquakes on structures and studies on seismic microzoning of the main cities of the state of Veracruz.

Armando Aguilar Meléndez

Doctor of Engineering, with honorable mention, from the Polytechnic University of Catalonia. He is a full-time professor of C degree in the Faculty of Civil Engineering of the University of Veracruz in Poza Rica. He is co-author of the CRISIS2014 computation code to estimate seismic danger in regions. He is also co-author of several publications in magazines and memoirs of national and international conferences.

Ana María Alarcón Ferreira

Master in Earth Sciences with a specialty in Seismology from UNAM, pursuing a doctorate at the Institute of Geophysics of UNAM. She worked at the National Center for Disaster Prevention (in the volcanic monitoring of Popocatepetl and other active volcanoes in Mexico); she also collaborated in the Center for Earth Sciences of the University of Veracruz. Speaker in national and international forums. Currently works in the Secretariat of Civil Protection of Veracruz.

Francisco Córdoba Montiel

He studied the Bachelor of Electronic Instrumentation and the Specialization in Microprocessor Systems at the Faculty of Electronic Instrumentation of the University of Veracruz. He completed his Master's in Science studies with an orientation in Seismology at the Postgraduate of Earth Sciences of the UNAM and is currently a Doctor of Science by the same Postgraduate.

Sergio R. Rodríguez Elizarrarás

Doctor of Science with a specialty in Geology, postgraduate in Earth Sciences at the National Autonomous University of Mexico. He is a Senior Researcher in the Department of Regional Geology of the Institute of Geology of the UNAM. He is currently collaborating in the Earth Science Center of the University of Veracruz. He has numerous publications in national and international circulation magazines.

Katrin Sieron

Has a PhD in Earth Sciences (Volcanology) at the National Autonomous University of Mexico (UNAM), she has a Bachelor and Master's degree in Geology (TU BergakademieFreiberg), including a scholarship exchange to Acadia University, Canada. Researcher at the Center for Earth Sciences of the University of Veracruz. She has published internationally in indexed journals, belongs to the National System of Researchers (SNI, level "C") and has participated in multiple research projects, in addition to being a professor at the Faculty of Economics.

María del Socorro Menchaca Dávila

Doctor in Higher Education in sustainable development, interdisciplinarity and complex systems in a UNESCO Chair of the UAEM, with a degree in Social Psychology from UNAM. Professor-Researcher at the University of Veracruz, of the Center for Earth Sciences. Academic coordinator of the Water Observatory for the State of Veracruz, OABCC (Water, Forests, Basins and Coasts), and participant in the University Project on Natural and Anthropic Risks (RINA).

Javier Bello Pineda

Doctor in Basin Ecosystems from Trent University (Canada), with a Master's in Marine Biology from CINVESTAV, a career Biologist from UNAM and a Professor from the Benemérita National School of Teachers, and Postdoctorate from the Coastal Development Center "(CDC), Kasetsart University (Thailand) Professor-Researcher at the University of Veracruz at the Institute of Marine Science Research Fisheries. He has worked as Coordinator of Protected Natural Areas in International Conservation Mexico - Gulf of California Program, Researcher at the National Fisheries Institute.

Ana Cecilia Travieso Bello

Biologist with a Masters and Doctorate in Ecology and Natural Resources Management. She is a professor/researcher at the Faculty of Economics of the University of Veracruz. It has the recognition of the Desirable Profile of the Teacher Improvement Program of the Ministry of Public Education. It belongs to the Network of Hydrometeorological and Climate Disasters of the National Council of Science and Technology. He has publications in books and magazines, national and international.

Carlos Manuel Welsh Rodríguez

Doctor in Sustainability from the Polytechnic University of Catalonia, he has a Post Dctorate at the National Center for Atmospheric Research (NCAR) in Boulder Colorado. He is currently a Researcher at the Center for Earth Sciences of the University of Veracruz; his line of research is developed around the local and regional impacts of global change. He has participated as a speaker in national and international conferences, has published books, book chapters, as well as articles in national and international journals. He was reviewer of the V Evaluation Report of the Intergovernmental Panel on Climate Change (IPCC) and is a member of the Hydrometeorological and Climate Disasters network of the National Council of Science and Technology (Redesclim).

Carolina Andrea Ochoa Martínez

Doctoral student in Engineering from the University of Veracruz. Is part of the Global Change Group of the Center for Earth Sciences of the University of Veracruz. Her line of research is based on the field of climate variability, climate change and the impacts of both. Has collaborated in several articles for national and international magazines as well as in several book chapters.

María Tania García López

Has a PhD in law from the University of Alcalá de Henares, Madrid, Spain, she has a Master in European Communities from the Center for European Studies of the University of Alcalá, a law degree from the same University and is a professional expert in e-learning 2.0 from the University National Distance Education, Spain. She is a full-time researcher at the University of Veracruz in the Faculty of Chemical Sciences and a member of the National System of Researchers of the National Council of Science and Technology (CONACYT), Mexico, level I.

Dainiz Evlyn Hernández Hernández

PhD student in Biological Sciences from the National Autonomous University of Mexico, has collaborated in various research projects, has a Master of Science from INECOL A.C. She has participated in the Inventory of Greenhouse Gases of Teocelo, as well as the update of the inventory of Greenhouse Gases 2004-2008 of the state of Veracruz, has published articles in national and foreign journals and has been a professor of the bachelor's degree in Geography of the University of Veracruz.

Saraí Guzmán Rojas

She is a Chemical Engineer graduated from the University of Veracruz. He has collaborated in the Department of Environmental Biotechnology of the Institute of Ecology A.C., and for the Earth Science Center of the University of Veracruz. Has participated in the preparation of the Veracruz Inventory of Greenhouse Gases 2000-2008 of the State Climate Change Program of the University of Veracruz.

Edgar Saucedo Acosta

He is a professor/researcher at the Institute of Research and Higher Economic and Social Studies of the University of Veracruz, has been a visiting professor at the University of Maastricht (Netherlands), the Mora Institute (Mexico), the Autonomous University of Sinaloa (Mexico) and the National Autonomous University of Mexico (Mexico), guest researcher of the Institute for Comparative Studies of Regional Integration of the United Nations University in Bruges (Belgium). He has publications on regional integration issues, with emphasis on the economic field and the European and Latin American supranational regions.

Samantha Rullán Rosanis

Professor/researcher of the Institute of Research and Higher Economic and Social Studies of the Universidad Veracruzana. Law degree with master's degrees in French law, geopolitics and international relations, and European Union law, and doctor in European studies with Mention of European Doctor. Guest researcher of INSEAD campus Fontainebleau, France and Singapore, and in the Program of Latin American Studies of the University of Cornell in the United States. Her lines of research are: European Union, innovation and mobile telephony in Latin America. Has participated as a speaker in National and International Conferences and has published books, book chapters and articles on the aforementioned topics.

Applied methodologies to the Earth Sciences is a work published by IETEC-Arana Editores in digital format in March 2015. The edition was in charge of Ignacio Mora González.

This book includes a selection of nine of the most important works presented in the First Days of the Earth Sciences, which are related to various methodologies applied for modeling the estimation of risk by natural phenomena, for monitoring seismic activity of volcanoes, mass movement processes, for the integral management of basins and instruments used in the fight against climate change in countries of the European Union.

It is the result of an editorial effort of the Center for Earth Sciences of the University of Veracruz where the advances in the study of natural phenomena and their relationship with anthropic phenomena, aimed at their application for disaster prevention and integral risk management.