Determinants of Vulnerability to Climate Change: Analysis of Municipalities in Mexico

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Vulnerability to climate change is a central concept for natural hazards and disaster management, ecology, public health, poverty, and climate impacts. A system's vulnerability to climate change is determined by exposure, physical configuration and sensitivity, their ability and opportunity to adapt.

Research estimates indexes of vulnerability for 2 058 municipalities in Mexico. The use of indicators is a useful tool to display summary information about phenomena, as it condenses the complex reality in simple terms.

The research goal is identify which variables determine vulnerability to climate change in 2058 municipalities in Mexico. The hypothesis is that vulnerability to climate change depends on sociodemographic characteristics (poverty --income--, education, health, demographic factors, dependence on agriculture); housing characteristics; natural resources and type of government in the region.

There is general consensus on the influence of social vulnerability to environmental hazards. However, there is no agreement about the use of proxy indicators for this broadly Füssel (2009) and Gall (2007). Regularly, the choice of indicators is based on theoretical functions or relationships, or both. However, questions the reliability and explanatory power, not only for the conceptual challenge, but by the absence of empirical evidence, standards and evaluation. Coupled with the lack of a conceptual framework, methodological flaws and limited information. Although social vulnerability indices are of increasing interest for their utility in the comparison between regions and countries.

This research will use deductive indices, based on previous work, and induction, based on principal component analysis. Data sources are Censo de Población y Vivienda (Census of Population and Housing) 2010, Encuesta Nacional de Gobierno, Seguridad Pública y Justicia Municipal (National Survey of Government, Municipal Public Safety and Justice) 2009 and Sistema Estatal y Municipal de Bases de Datos (State and Municipal System Database) 2005.

With respect to the proposed indicators, research is based mainly on research New Indicators of Vulnerability and Adaptive Capacity, of Adger, et al., (2004), which establishes groups of factors, and Centro Nacional de Prevención de Desastres (Cenapred) (2006), Guía Básica para la Elaboración de Atlas Estatales y Municipales de Peligros y Riesgos (Basic Guide to Atlas Development of State and Local Hazard and Risk) and the Social Vulnerability Index, Susan L. Cutter, *et al.* (2003). Vulnerability to climate change is determined based on the following nine dimensions:

Economic well. The poorest regions face higher risk levels. It is recognized that the poorest people tend to live in more dangerous places, such as on slopes or flood plains. This population is located in marginalized areas, sometimes with limited access to public goods such as water. It recognizes that disasters not only generated by climate change, exacerbating poverty and vulnerability. Based on available information, using the percentage of employed people get up to twice the minimum wage income, the percentage of employed people who have no income and the percentage of the population receiving help from people living in another country (remittances) and the government as income diversification is a measure to counteract environmental disaster problems; Additional Total Current Income Per Capita per month, Consejo Nacional de Evaluación de la Política de Desarrollo Social (Coneval) (National Council for Evaluation of Social Development Policy).

Health. Lack of health care leads to greater vulnerability to extreme events. The lack of adequate health impact on the population is less made possible for disasters. Diseases affecting the economically active population (EAP) and require attention of the State or of the same society. Households where caring for the sick,

they have less time, money and energy to devote to mitigate impacts to extreme risks. The diseases are closely linked to poverty, in terms of cause and effect. Using the percentage of people not entitled to medical services (Cenapred) and the infant mortality rate (Cenapred), refers to the ability of an infant to survive the first year of life and is a measure of health care .

Education. It is likely that less educated people are vulnerable to climate risks by geographic location and quality of life, for its association with the marginalization and poverty. This population has little political participation and regularly needs are not met by the rulers. In addition, people with less education tend to rely on economic activities related to climate, such as agriculture. For its part, the adaptation is sometimes associated with conflicts of interest, where people with more education have better position to negotiate equitable solutions. Thus, using the percentage of illiterate population and average education level and percentage of the population aged 6 to 14 who attend school.

Housing. The settlements, infrastructure and transport systems determine the physical vulnerability as to extreme events such as rain, floods and storms are differential effects on the territory. The infrastructure can influence the feasibility and effectiveness of aid distribution programs as disaster response. For this dimension the following variables will be used for housing: no drain without electricity, walls and scrap cardboard sheets, floor, no fridge and no running water.

Government. State institutions influence the level of vulnerability. If you are inefficient or corrupt are associated with lack of adequate health care, housing and sanitation, can leave the maintenance of physical infrastructure. In addition, actions will do little to disaster relief. The variable used is the existence of a transparency and / or corruption, the National Survey of Government, Municipal Public Safety and Justice 2009.

Demographic factors. The population characteristics will influence social vulnerability, the larger dependent population in the regions will be more prone to have vulnerability. The selected variables are percentage of inactive population

ages (0 to 14 years and 65 and over), the dependency ratio, population density, the average age of the population and population dispersion, which is calculated by the percentage people in towns with fewer than 2,500 inhabitants compared to the total population of the municipality, as population dispersal occurs primarily in small towns whose conditions of scarcity and delay in the availability of public services are a problem. These locations have the highest fertility rates, infant mortality and absence or deficiency of basic services: water, sewer, electricity, telephones and roads.

Population. Disability and indigenous population. People with disabilities and indigenous people suffer from discrimination because of their condition. It uses variable percentage of the population with disabilities (for walking, moving, up or down, look even wear glasses, talk, communicate or talk, hear even using hearing aids, dressing, bathing, eating, paying attention or learn simple things with mental limitation) and the percentage of indigenous population (indigenous language speakers).

Dependence of agriculture. Drought is one of the major risks associated with climate variability and change. The population engaged in agriculture will be particularly at risk for this phenomenon, since agriculture is the main economic activity sensitive to climate, in most of the world. For this estimate includes the population employed in agriculture.

Natural Resources. The ability to adapt to climate change depends largely on the availability of natural resources, particularly water resources. Deforestation, fragmentation of ecosystems and pollution can increase a region's ecological vulnerability to climate change. Using the percentage of grassland surface, forest, jungle, other vegetation, secondary.

Principal component analysis

Analogous to social vulnerability index, Cutter, et al. (2003) those variables used in factor analysis, principal component. This statistical tool generates solid and consistent set of variables that can be monitored over time to assess changes in overall vulnerability. The technique also facilitates the replication of other variables in spatial scales. Then disaggregate the social vulnerability index by sex for all municipalities in Mexico.

Factor analysis serves to reduce data grouped by common factors to explain factors (in this case dimensions). It is a method that helps to identify factors that explain the pattern of correlations within a set of observed variables. Analysis is used to reduce data regularly to identify a small number of factors that explain most of the observed variance.

In order to validate the relevance of using this statistical method, statistical tests are used: Bartlett specificity test and measure of sampling adequacy of Kaiser-Meyer-Olkin (KMO). The Bartlett test of specificity of the hypothesis that the correlation matrix is an identity matrix. That is, if one accepts this hypothesis would be to have a high significance level. Which, would question the use of any type of factor analysis, because it implies that there is no correlation between the variables. Meanwhile, the measurement of sample suitability as KMO allows knowing which data are suitable for use factorial analysis, by comparing the values of the correlation coefficients observed partial correlation coefficients. It is considered that if KMO is between 0.9 and 1 factorial model results will be excellent, will be good if they are between 0.8 and 0.9; acceptable, between 0.7 and 0.8; regular, between 0.6 and 0.7, and the lower limit of acceptance, but acceptable, they are between 0.5 and 0.6, and unacceptable when less than 0.5.

KMO y prueba de Bartlett

Prueba de esfericidad de Bartlett	Chi-cuadrado aproximado	41685.83
	gl	351
	Sig.	**0.00**
Medida de adecuación muestral de Kaiser-Meyer-Olkin.		**0.877**

The results of the Bartlett test of sphericity has a significance level of zero, therefore, the null hypothesis is rejected, it is possible and appropriate to use factor analysis. Furthermore, the KMO test has a value of 0.877, which means that the results of the factor model are acceptable.

Table of communalities

Variables	Initial	Extraction
% Population (with 1 and 2 SM)	1	0.833
% Population (with 0 SM)	1	0.881
% Population with income from remittances	1	0.688
% Population with income from government grants	1	0.884
% Population without medical facilities	1	0.554
% Illiterate population	1	0.814
Average schooling	1	0.930
% Population 6-14 years attending school	1	0.631
% Population ages inactive	1	0.858
Demographic dependency ratio	1	0.845
% Population with disabilities	1	0.705
% Population in the primary sector	1	0.751
% Population in households without drainage	1	0.700
% Population in households without electricity	1	0.511
% Population in dwellings with walls or cardboard waste	1	0.482
% Population in households without a refrigerator	1	0.856
% Population in homes without water	1	0.457
Average number of persons in the household	1	0.764
Average number of people in rural	1	0.349

Population Density	1	0.475
Total Current Income Per Capita monthly	1	0.855
% Area no natural resources	1	0.497
Gini Coefficient	1	0.466
Infant mortality rate	1	0.718
% Indigenous	1	0.633
Government	1	0.429
Average age	1	0.826

Extraction Method: Principal Component Analysis.

The principal components method, which means that it is possible to explain 100% of the observed variance, for this reason all initial communalities (the second column) have a value of one. With these results we can begin to ask whether some variables can be excluded from the analysis.

The percentages of the total variance is obtained by dividing the eigenvalue corresponding to the sum of the eigenvalues (which coincides with the number of variables). The statistical procedure gets as many factors as eigenvalues greater than one has the matrix tested. Estimated six factors that explain 67.7% of the variance of the original data. This matrix shows that the first factor explained 38.3% of the variance and the six factors explained 70.0% near the variance.

Total Variance Explained

Component	Initial eigenvalues			Amounts of the saturations of the extraction squared		
	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative
1	10.315	38.203	38.203	10.315	38.203	38.203
2	2.712	10.046	48.249	2.712	10.046	48.249
3	1.510	5.592	53.842	1.510	5.592	53.842
4	1.371	5.077	58.919	1.371	5.077	58.919
5	1.300	4.816	63.735	1.300	4.816	63.735
6	1.182	4.376	68.111	1.182	4.376	**68.111**

7	0.918	3.401	71.512			
8	0.865	3.203	74.715			
9	0.841	3.114	77.830			
10	0.816	3.023	80.853			
11	0.722	2.675	83.528			
12	0.695	2.574	86.102			
13	0.612	2.268	88.370			
14	0.556	2.060	90.430			
15	0.514	1.902	92.332			
16	0.463	1.714	94.047			
17	0.314	1.165	95.212			
18	0.265	0.981	96.192			
19	0.247	0.914	97.106			
20	0.169	0.624	97.731			
21	0.154	0.570	98.301			
22	0.141	0.522	98.823			
23	0.137	0.508	99.331			
24	0.086	0.320	99.651			
25	0.054	0.200	99.851			
26	0.037	0.136	99.988			
27	0.003	0.012	100.000			

Método de extracción: Análisis de Componentes principales.

There are variables that can be skipped because they tie and help provide valuable information to the analysis. For this purpose, some modifications were made (removing variables) to see if you get better results. The following variables are ignored:

•% Population (with 0 SM)

•% Population with income from government grants

•% Illiterate population

• Average schooling

•% Population 6-14 years attending school

•% Population in the primary sector

•% Population in households without electricity

•% Population in dwellings with walls or cardboard waste

•% Population in homes without water

• Average number of persons in the household

• Average number of people in rural

• Total Current Income Per Capita monthly

•% Area no natural resources

• Gini Coefficient

• Infant mortality rate

•% indigenous Population

This data gives the following.

Table of communalities

Variables	Variables	Variables
% Population without medical facilities	1	0.749
% Population in households without a refrigerator	1	0.835
% Population (with 1 and 2 SM)	1	0.813
% Population 6-14 years attending school	1	0.731
% Population with income from remittances	1	0.706
% Population with disabilities	1	0.768
Average age	1	0.779
% Population in households without drainage	1	0.746
Population Density	1	0.654
Government	1	0.533

% Population ages inactive	1	0.805

Extraction Method: Principal Component Analysis.

Principal Component Matrix shows the correlations between the original variables and each of the five factors. With these variables estimated the percentage of variance explained. Five factors are obtained, which explain 73.8% of the variance of the original data.

Total Variance Explained

Component	Initial eigenvalues			Amounts of the saturations of the extraction squared		
	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative
1	2.713	24.663	24.663	2.713	24.663	24.663
2	2.106	19.142	43.805	2.106	19.142	43.805
3	1.202	10.930	54.735	1.202	10.930	54.735
4	1.089	9.900	64.635	1.089	9.900	64.635
5	1.009	9.174	73.809	1.009	9.174	**73.809**
6	0.797	7.243	81.052			
7	0.719	6.534	87.585			
8	0.549	4.995	92.581			
9	0.377	3.427	96.008			
10	0.264	2.397	98.405			
11	0.175	1.595	100.000			

Extraction Method: Principal Component Analysis.

The five factors are distributed as follows.

Matrix Components*

Variables	Components				
	1	2	3	4	5
% Population (with 1 and 2 SM)	-0.150	-0.054	**0.701**	-0.173	0.578
% Population with income from remittances	-0.157	**0.696**	-0.168	-0.402	-0.174

% Population without medical facilities	0.364	0.130	-0.304	-0.027	**0.627**
% Population 6-14 years attending school	-0.438	0.151	0.149	**0.665**	-0.002
% Population ages inactive	**0.775**	0.394	0.033	-0.051	-0.208
% Population with disabilities	-0.108	**0.865**	0.067	0.145	0.061
% Population in households without drainage	**0.775**	0.176	0.067	0.356	-0.063
% Population in households without a refrigerator	**0.878**	-0.019	0.115	0.273	0.107
Population Density	-0.298	-0.296	**-0.544**	0.359	0.187
Government	-0.230	-0.133	**0.390**	0.214	-0.367
Average age	-0.457	**0.724**	-0.024	0.200	0.166

Extraction Method: Principal Component Analysis.

* 5 components extracted

Once identified five factors, we estimate the index calculation is homologous to the Human Development Index (HDI). Four sub-indices are created with the determination of minimum and maximum values (limits) of each factor, transforming them into indices with values between 0 and 1, and can be comparable. The value close to 1 is indicative of greater vulnerability, contrary to this, the closer to 0 the region have less vulnerability. The normalization of variables are as follows:

$$\text{Dimension index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

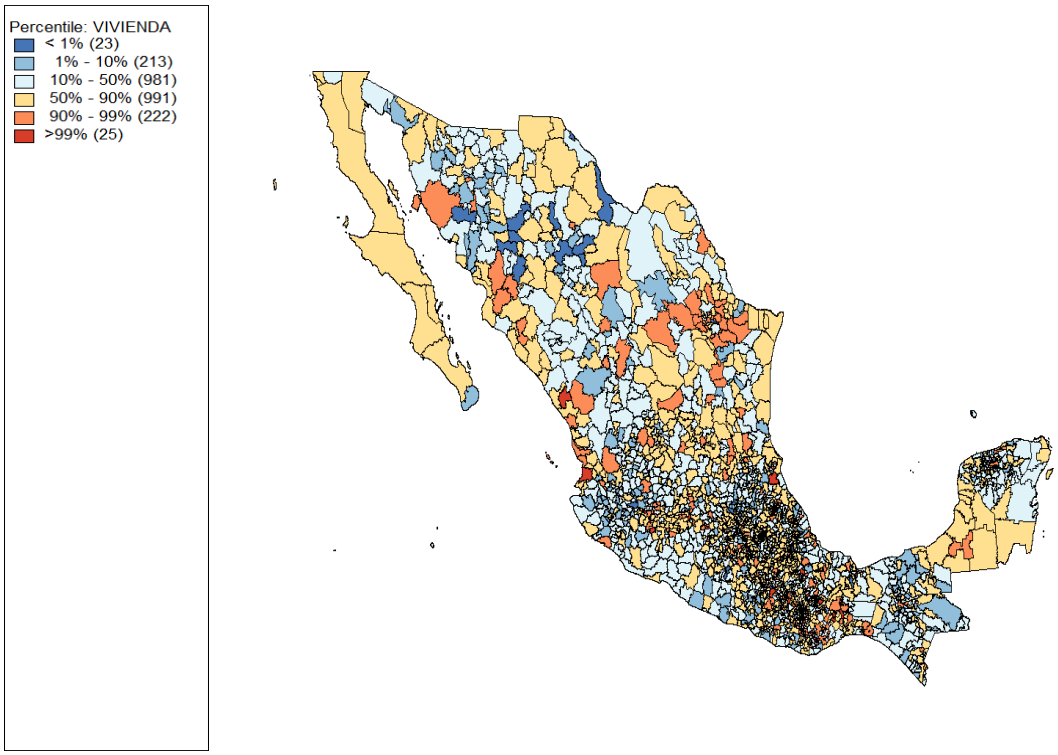
Based on factor analysis specifies five factors:

1. Households:

% Population in households without a refrigerator

% Population in households without drainage

% Population ages inactive

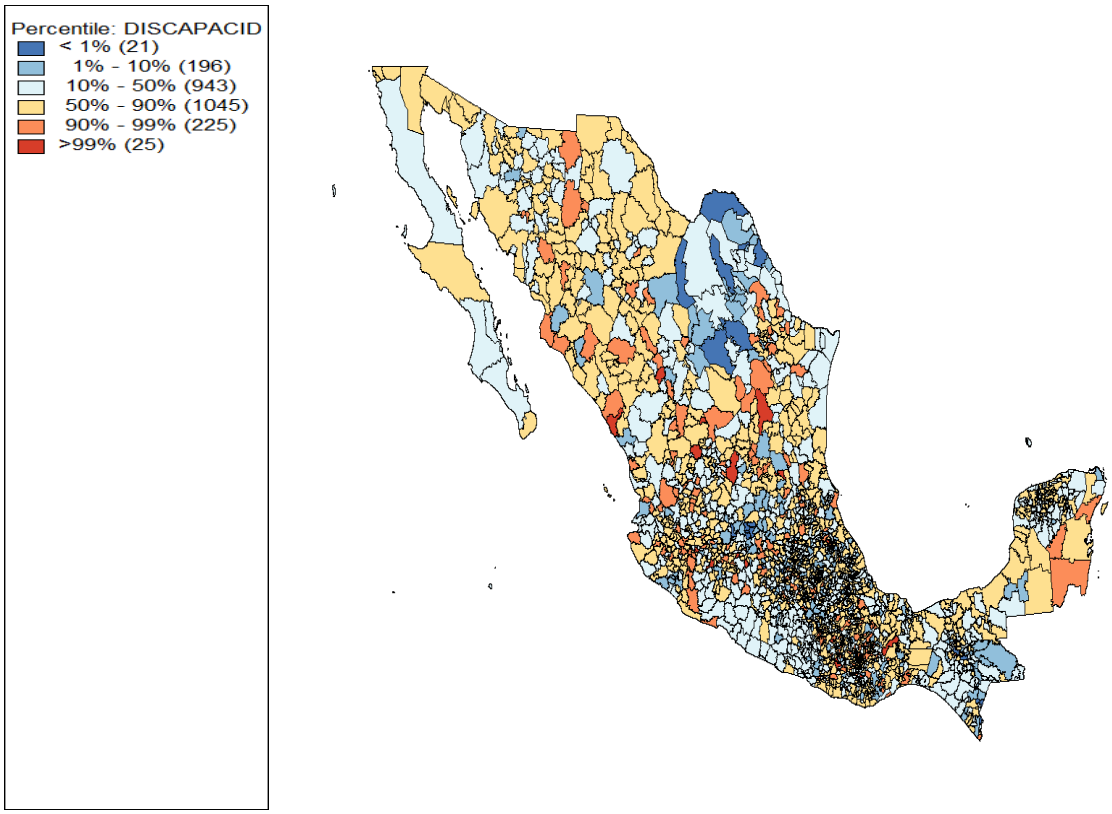


2. Disability, age and remittances:

•% Population with income from remittances

•% Population with disabilities

• Average age

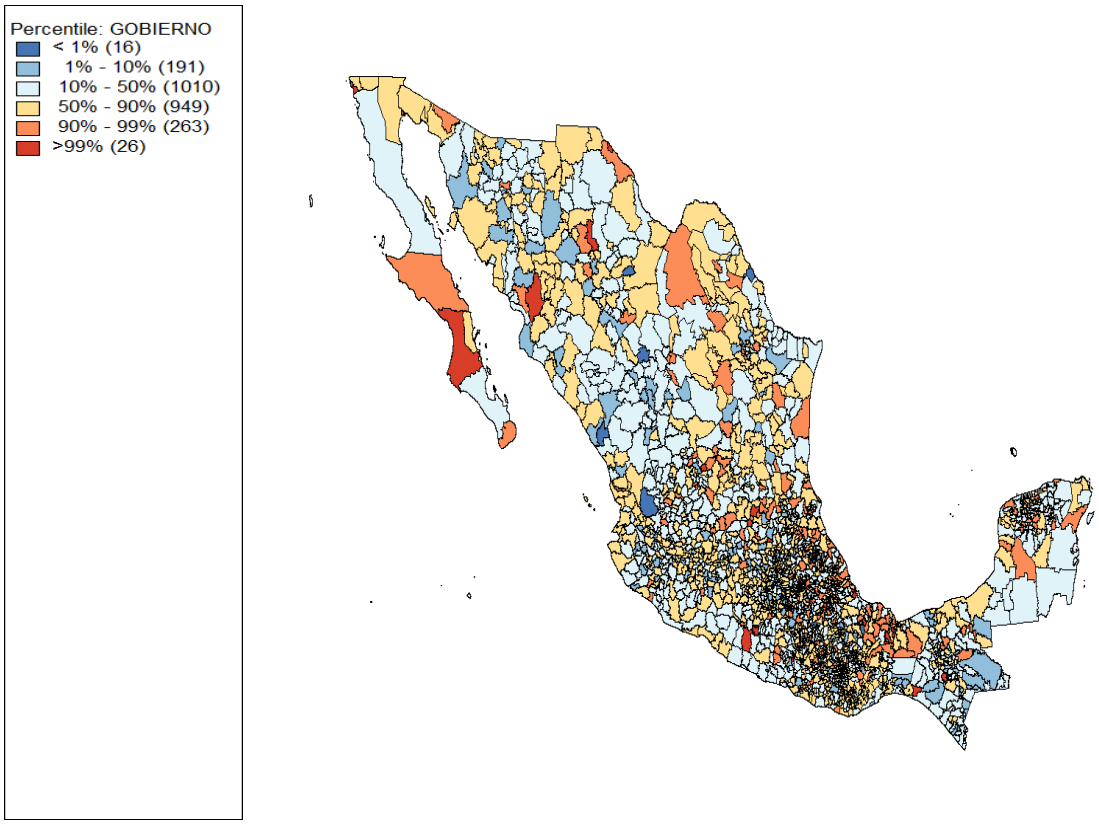


3. Government and education:

• Government

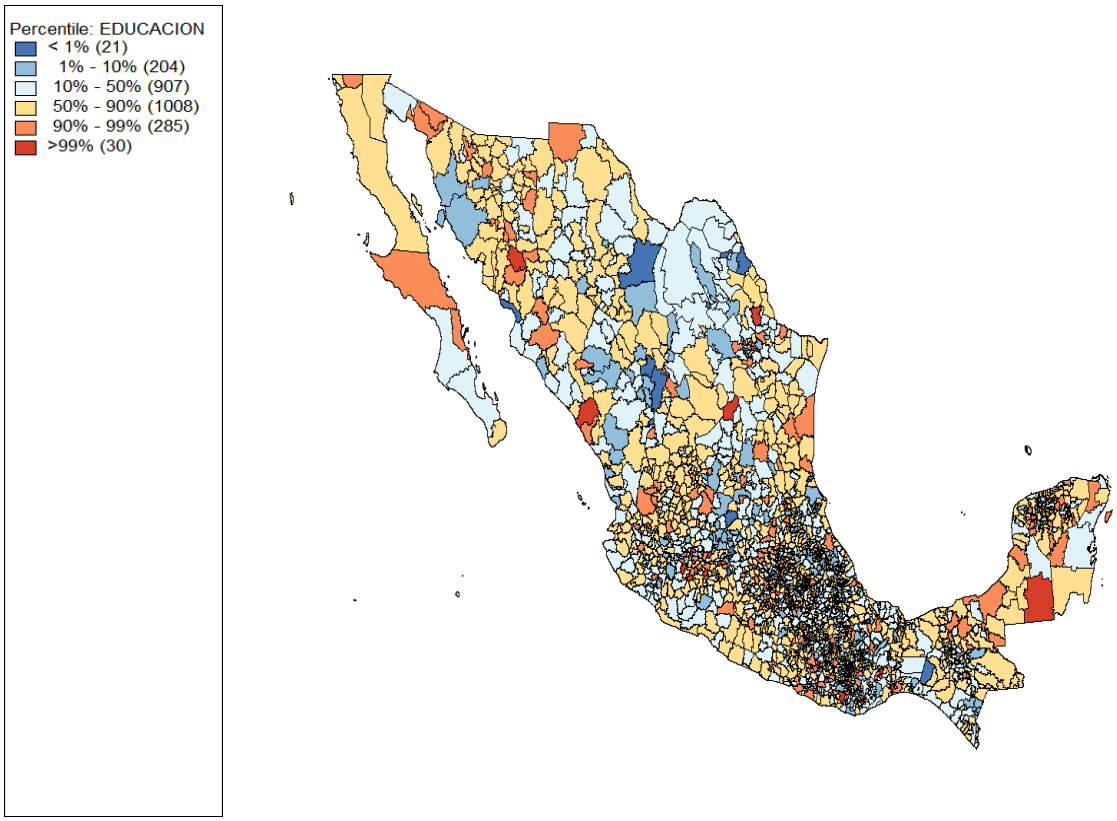
•% Population (with 1 and 2 SM)

• Population Density



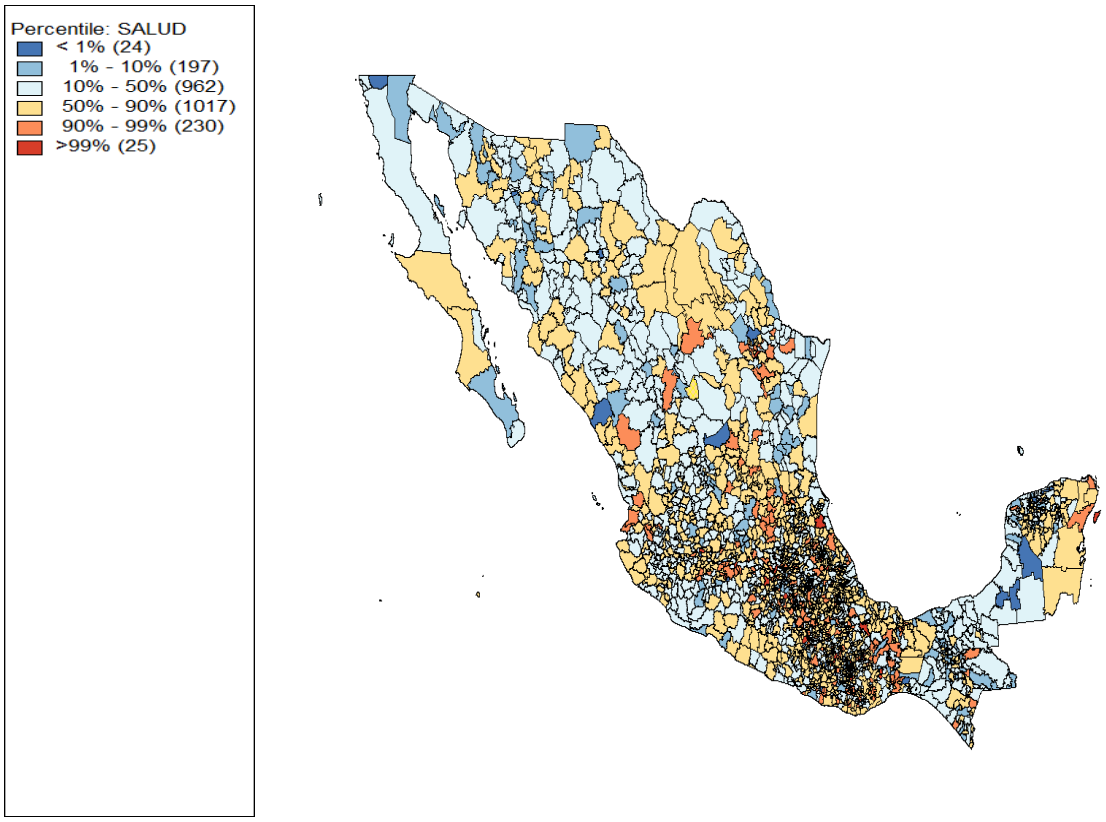
4. Education

•% Population 6-14 years attending school



5. Health

•% Population without medical facilities



The vulnerability of municipalities is varied for the five components. However, the center of the country presents more vulnerable by their social needs and the high concentration of population. This review identifies focus areas that must be addressed to avoid risks to the population living in the most vulnerable regions to climate events.

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