Mapping of Mexico City's susceptibility to sinkhole formation using the weights of evidence method

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Introduction

The increase in urbanization has generated various problems such the formation of sinkholes. In Mexico City, this phenomenon has been recorded since 2017, creating severe risks to the population and civil structures throughout the city.

For this reason, this work focuses on identifying the areas with the highest potential for presenting this phenomenon, using the weight of evidence method. This is to monitor the most susceptible areas and prevent possible future damage.

Figure 1. Effects of the presence of sinkholes in an urban area.

Record of damages caused by sinkholes in Mexico City

The record has 565 observations between 2017 and 2019.

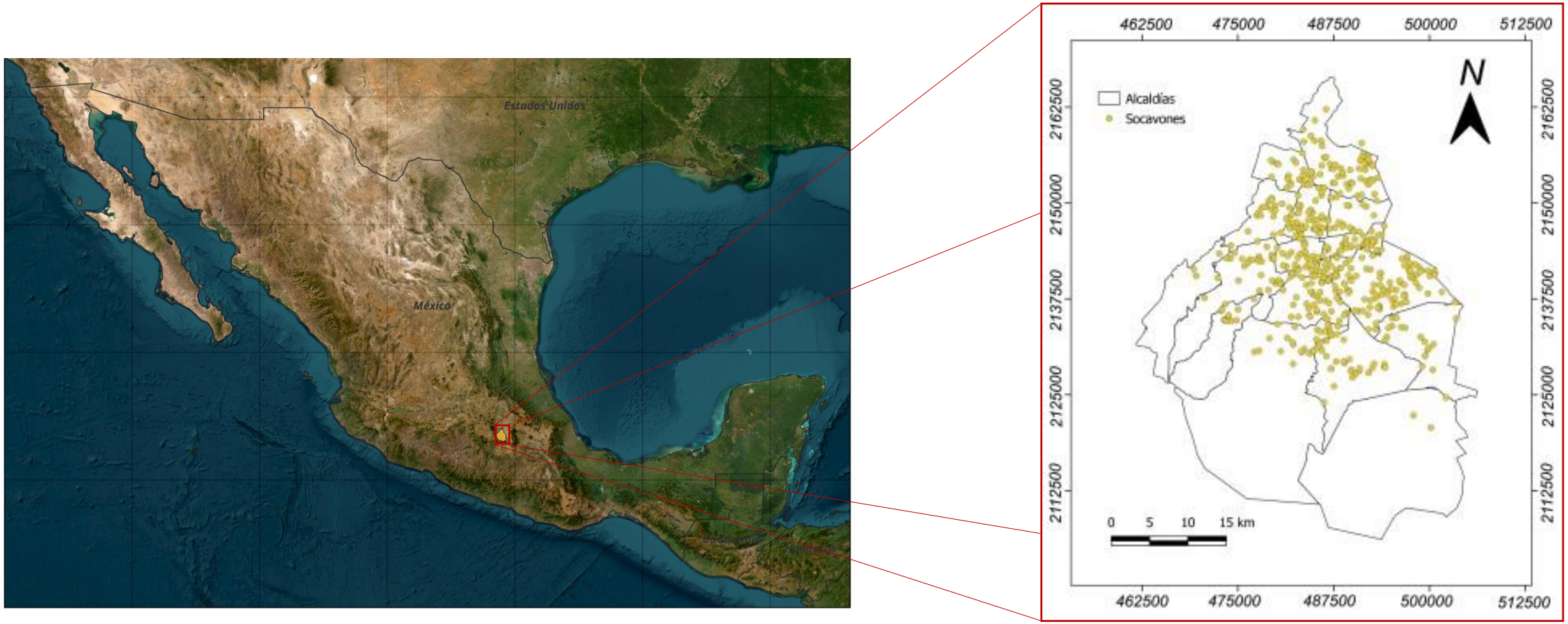
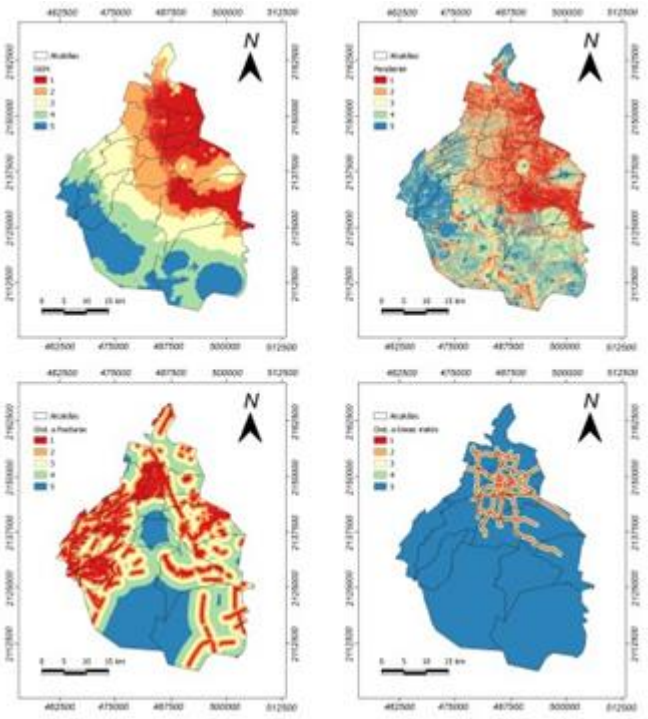


Figura 2. Mexico and record of sinkhole damage in Mexico City.

Metodology

Identification and characterization of conditioning factors → *Application of the Weights of Evidence method* → *Identification of susceptible areas*



$$W^+ = ln\left[\frac{P(B/D)}{P(B/\overline{D})}\right]$$

$$W^- = ln\left[\frac{P(\overline{B}/D)}{P(\overline{B}/\overline{D})}\right]$$

$$C = W^+ + W^-$$

$$S^2(W^+) = \frac{1}{N(B \cap D)} + \frac{1}{(B \cap D)}$$

$$S^2(W^-) = \frac{1}{(\overline{B} \cap D)} + \frac{1}{(\overline{B} \cap \overline{D})}$$

$$S(c) = \sqrt{C} \qquad W = \left(\frac{C}{S(C)}\right)$$

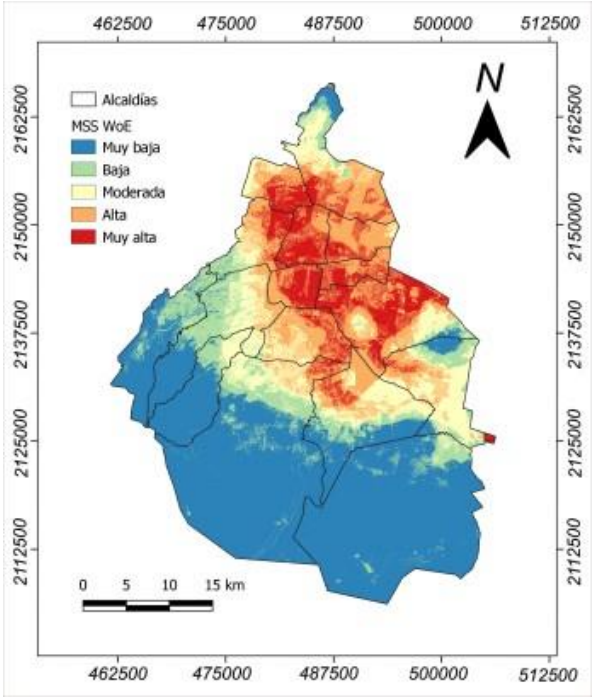


Figura 3. Methodology for calculating the susceptibility of a phenomenon using the weights of evidence method.

Results - Conditioning factors

The conditioning factors used for this study:

a) Sinkage rate

b) Ground elevation

c) Slope

d) Distance to faults

e) Distance to fractures

f) Distance to subway lines

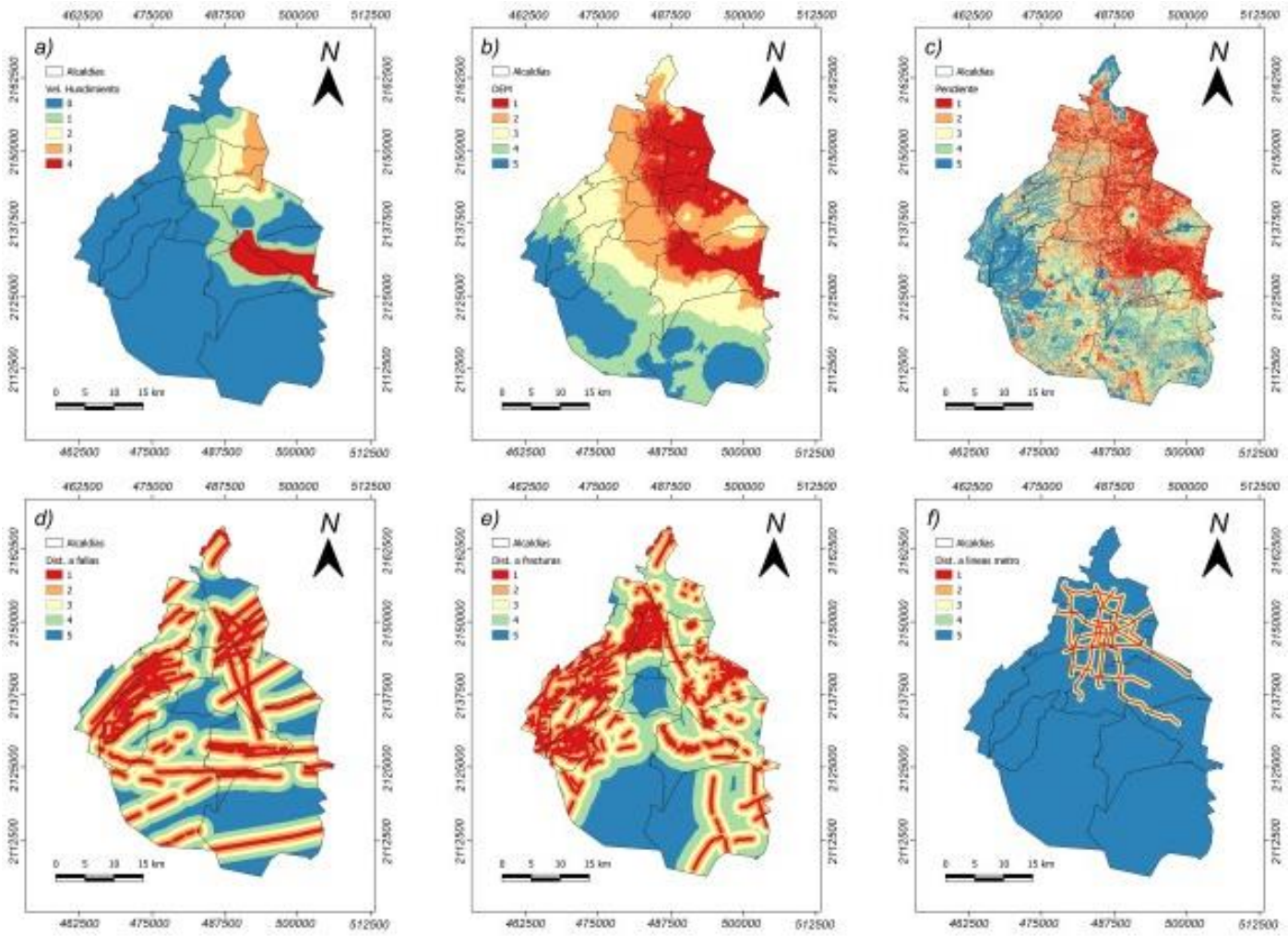


Figure 4. Characterized conditioning factors

Results - Conditioning factors

The conditioning factors used for this study:

g) Groundwater drawdown

h) Distance to roadways

i) Density of mines

j) Density of wells

k) Density of drainage

l) Density of waterlogging

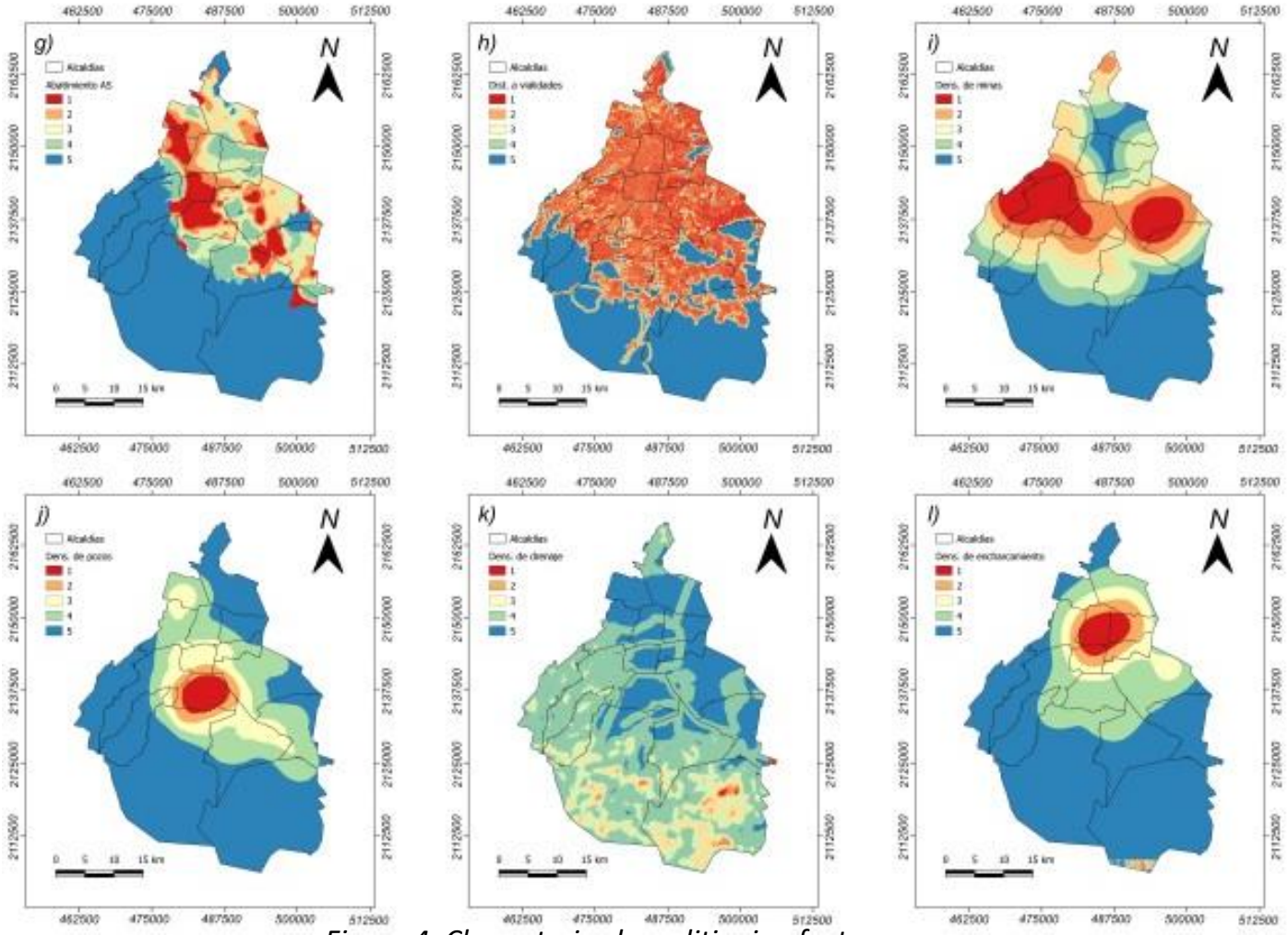


Figure 4. Characterized conditioning factors

Results - Conditioning factors

The conditioning factors used for this study:

n) Land use

m) Geology

o) Density of water leaks

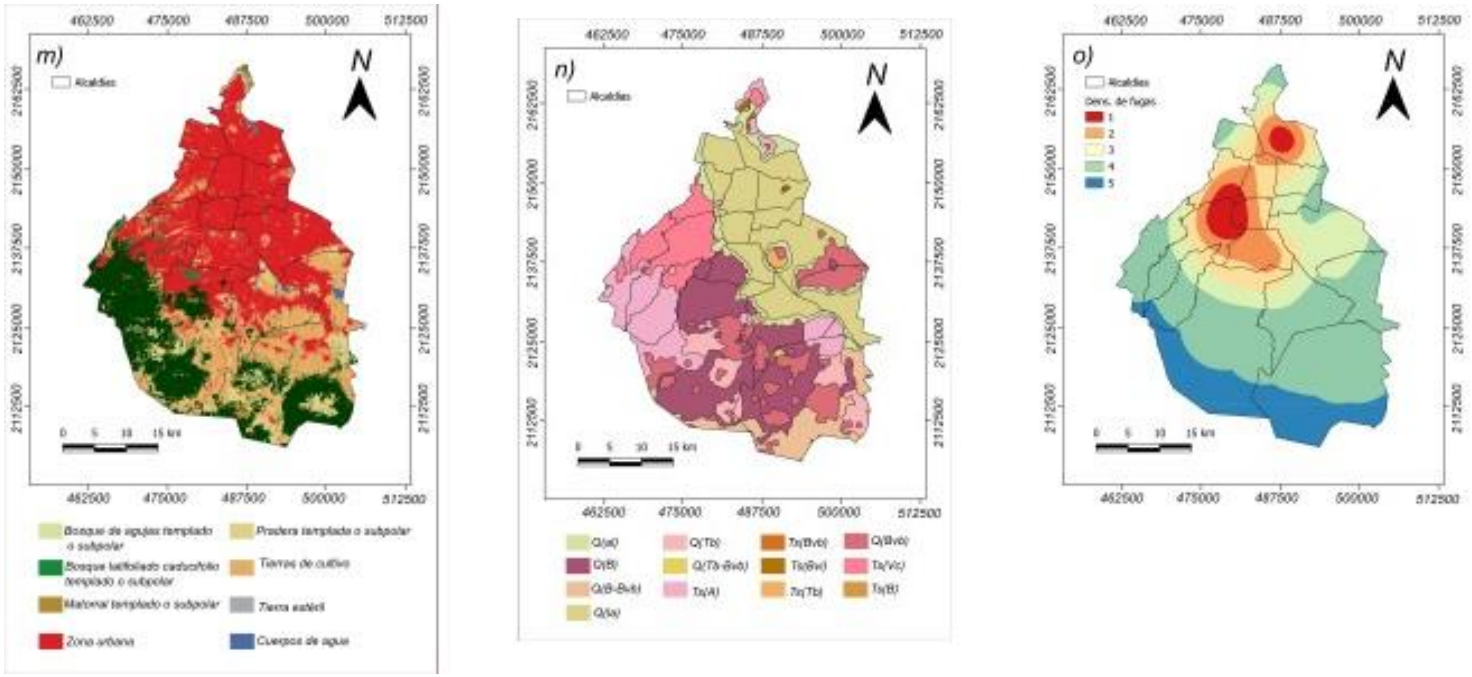


Figure 4. Characterized conditioning factors

Results - Weights of Evidence

The final weights of the factors, density of mines, density of water leaks, and sinkage rate, show a linear behavior where an increase in the class value increases the probability of sinkhole formation. Otherwise for the factors: drainage density, soil elevation, slope and distance to fractures.

For the other factors, there is no defined behavior in the weights. However, it can be observed that in certain classes, there is a higher probability of the phenomenon occurring.

Table 1. Final weights (W) for factors with linear behavior.

Class	Dens.Drainage	Slope	Sinkage rate	Water leaks	Dist. Fractures	Ground elev.	Dens. Mines
0	14.94		-18.62	-	-		-12.64
1	-4.83	8.90	16.42	-13.41	6.58	15.11	1.89
2	-7.14	9.74	9.22	7.96	0.19	12.42	2.35
3	-3.46	-1.99	5.95	9.79	0.13	-5.40	4.01
4	-	-7.20	-0.50	11.82	-1.33	-4.90	6.45
5	-	-8.29		7.36	-5.52	-	6.68

Table 2. Final weights (W) for factors with undefined behavior

Class	Dist. Roadways	Subway lines	Dist. Faults	Dens. Wells	Waterlogging	GW drawdown
0	-	-16.78	-	-	-	-18.00
1	24.59	6.84	0.54	-15.84	-20.10	5.14
2	-6.05	8.21	-0.13	8.74	9.54	7.11
3	-	4.81	0.58	7.38	15.34	10.54
4	-	8.42	3.31	8.40	8.61	9.93
5	-	8.49	-4.22	5.31	10.18	7.70

Type Geology		Land use	
Clase	W	Clase	W
Q(al)	7.01	Agua	-
Q(B)	-8.14	Zona urbana	24.07
Q(B-Bvb)	-	Tierra esteril	-
Q(Bvb)	-4.96	Tierra cultivo	-5.37
Q(la)	18.51	Pradera temp.	-
Q(Tb)	-3.53	Matorral temp.	-
Q(Tb-Bvb)	-	Bosque lact.	-
Ts(A)	-5.81	Bosque temp.	-
Ts(B)	-		
Ts(Bvb)	-		
Ts(Bvi)	-		
Ts(Tb)	3.92		
Ts(Vc)	1.02		

Results - Map of sinkhole susceptibility

The areas with the highest potential for sinkhole formation are located in the central-north and eastern parts of Mexico City.

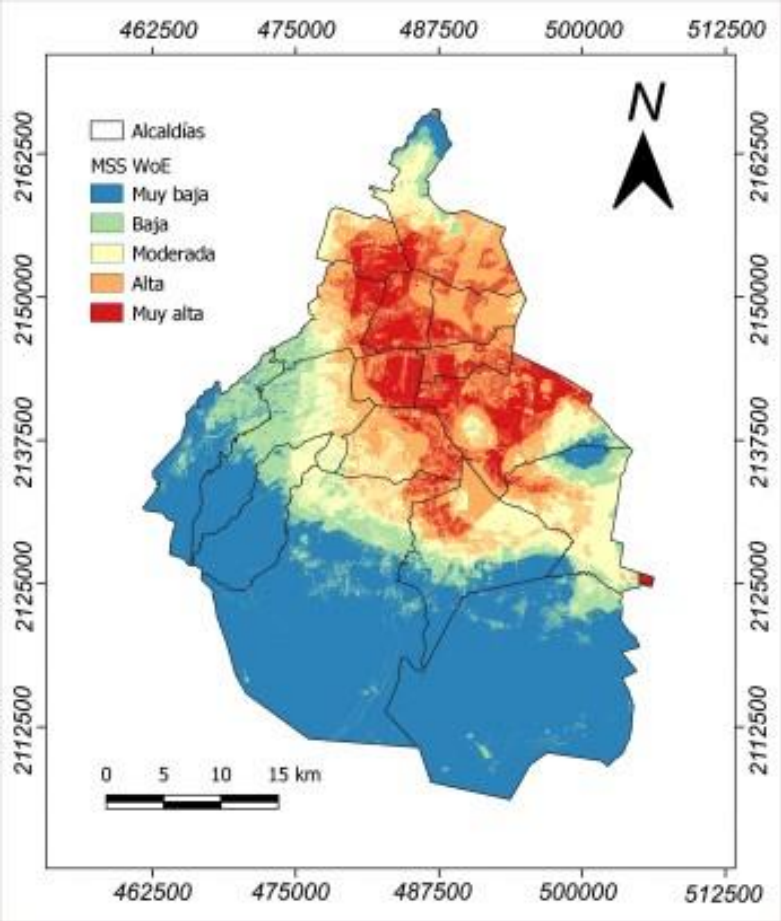


Figure 5. Map of susceptibility to sinkhole formation in Mexico City.

Conclusions

The use of conditioning factors and the weight of evidence method identified the areas with the highest potential for sinkhole formation in the central-north and eastern parts of Mexico City.

Several factors showed a linear behavior in the final weights, such as ground elevation, slope, drainage density, and distance to fractures.

Future work will involve analyzing other factors to verify if they can improve the accuracy of the susceptibility estimation. Additionally, a cross-validation will be performed to estimate the precision of the model.

Thank you for your attention

If you have any questions, you can send me an email at: garciacrz93@gmail.com

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