Correlation analysis between the subsides reported as sinkholes and the thickness of the clays of the shallow aquifer in Mexico City.

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Introduction

Mexico City was founded on Texcoco Lake.

The excessive growth of the city has generated a high demand for water.

Generating soil subsidence in the city.

Objective to analyze the relationship between the different criteria that can generate the presence of sinkholes in the study area.

Image 1. Context of México city

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Methodology

The steps to carry out the project:

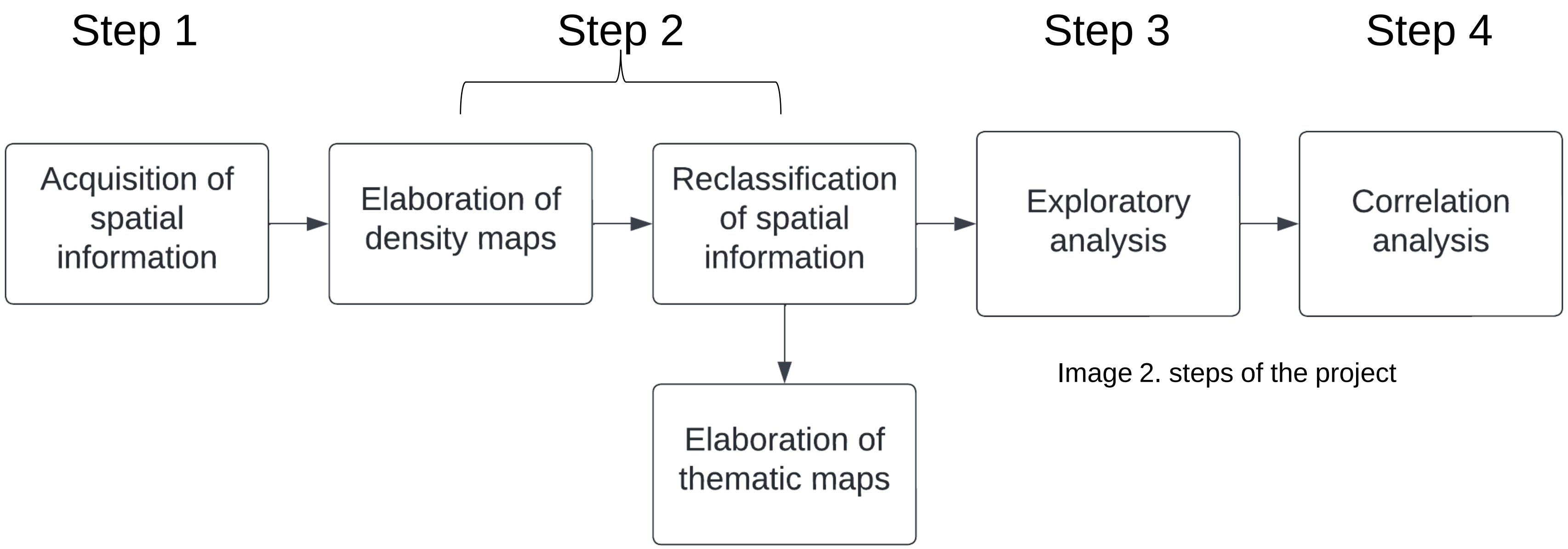

Image 2. steps of the project

Methodology

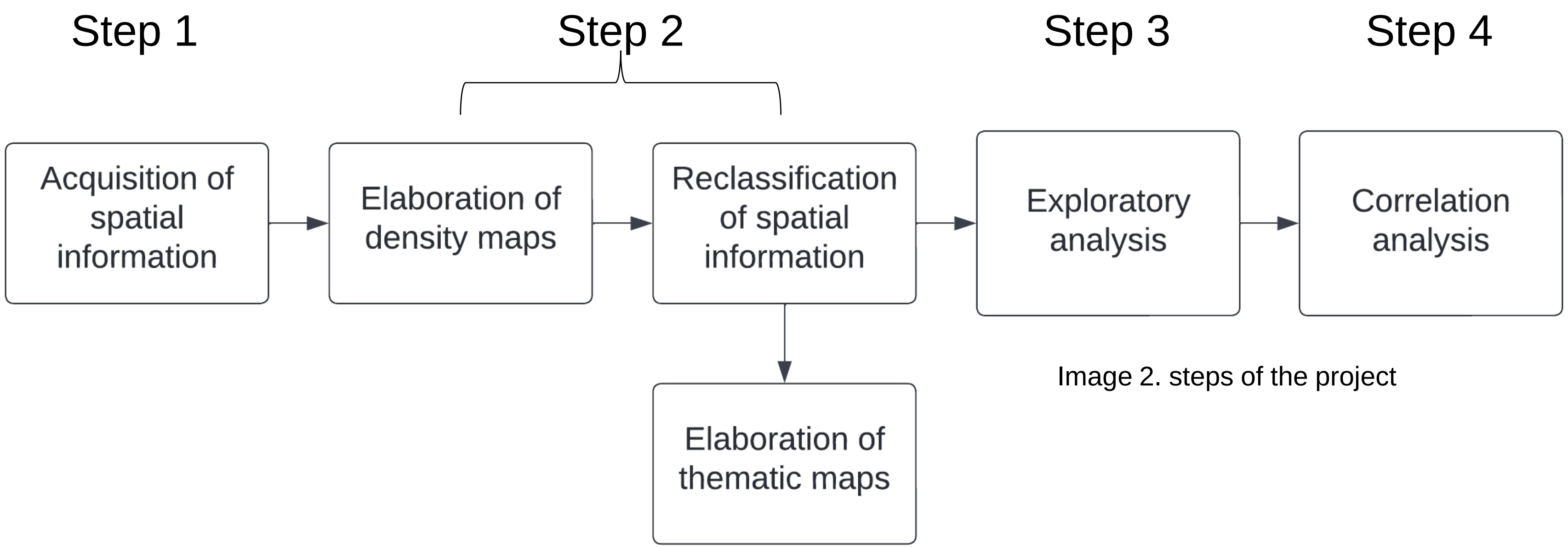

Image 2. steps of the project

Table 1. Reclassification of spatial information.

Class	Depth clay (m)	Sinkholes density (u/Km^2)	Wells density (u/Km^2)	Dist. to streams (m)	Elevation (m)	Dist. to faults (m)	Dist. to fratures (m)	Slope (degree)	Population (hab/m^2)	Dist. to roads (m)
0	-	-	-	> 200	-	> 400	> 400	-	-	> 150
1	0 - 16.52	0 - 0.19	0 - 0.28	200 - 150	< 2637.5	400 - 300	400 - 300	< 2	-	150 - 100
2	16.52 - 34.78	0.19 - 0.6	0.28 - 0.87	150 - 100	2637.5 - 3069	300 - 200	300 - 200	2 - 5	0.008 - 0.013	100 - 50
3	34.78 - 53.90	0.6 - 1.05	0.87 - 1.66	100 - 50	3069 - 3500.5	200 - 100	200 - 100	5 - 12	0.013 - 0.018	50 - 30
4	53.90 - 75.20	1.05 - 1.56	1.66 - 2.79	50 - 30	> 3500.5	100 - 50	100 - 50	> 12	0.018 - 0.024	30 - 20
5	75.20 - 110.86	1.56 - 2.54	2.79 - 5.03	< 30	-	< 50	< 50	-	> 0.024	< 20

Subsidence vel.	Rock type	Soil type	Geotechnical zone
0	-	-	-
1	(2) Ígnea extrusiva. Toba	(1) Bosque de coníferas	(1) Lomas
2	(3) Ígnea extrusiva. Brecha	(15) Suelo agrícola	(2) Transición
3	(4) Ígnea extrusiva. Basalto	(17) Asentamiento urbano	(3) Lacustre
4	(5) Sedimentaria detrítica	-	-

Methodology

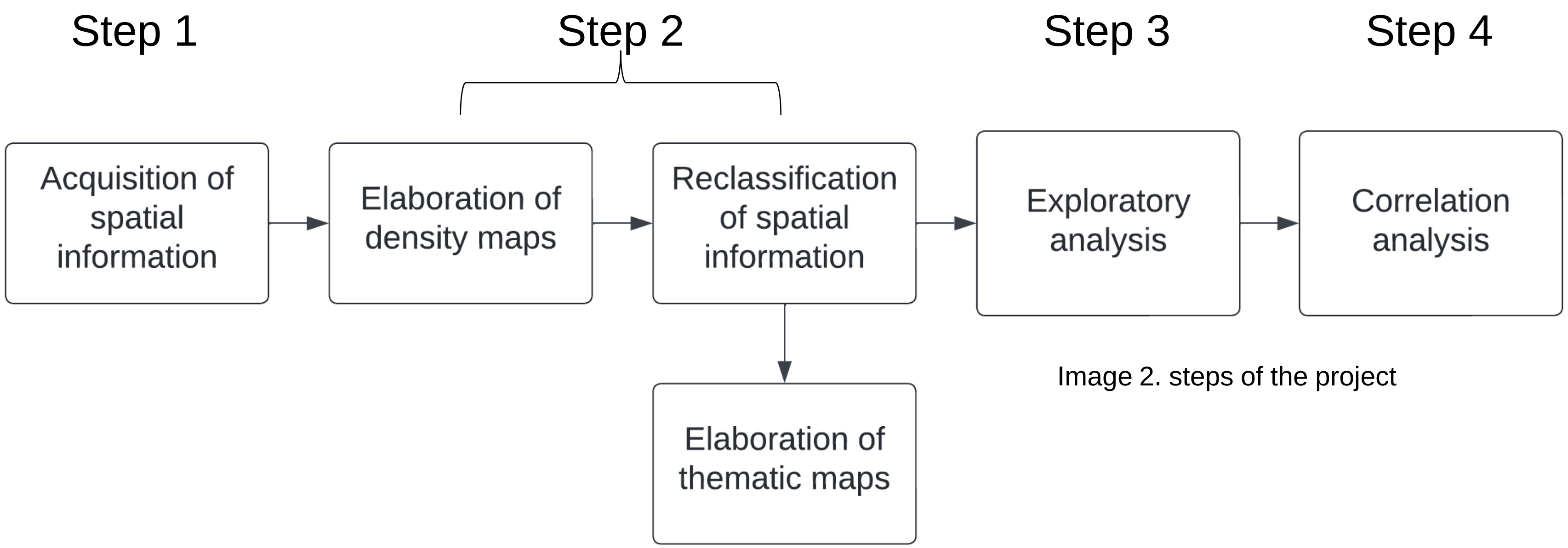

Image 2. steps of the project

Chi square Test

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

O = observed frequency
E = expected frequency

Cramer's coefficient

$$V = \sqrt{\frac{\chi^2}{n(L-1)}}$$

χ^2 = Chi square value
n = total number of observations
L = min. Number of rows or columns

Lineal model regression

$$Y = \beta_0 + \beta_1 X_1 + \delta_1 D_1 + \varepsilon$$

X = variable
β, δ = coefficients
D = categoric variable
ε = residual

Results - Maps of variables

The following maps allowed us to identify the areas with the highest concentration of sinkholes, which are in the central part of the city.

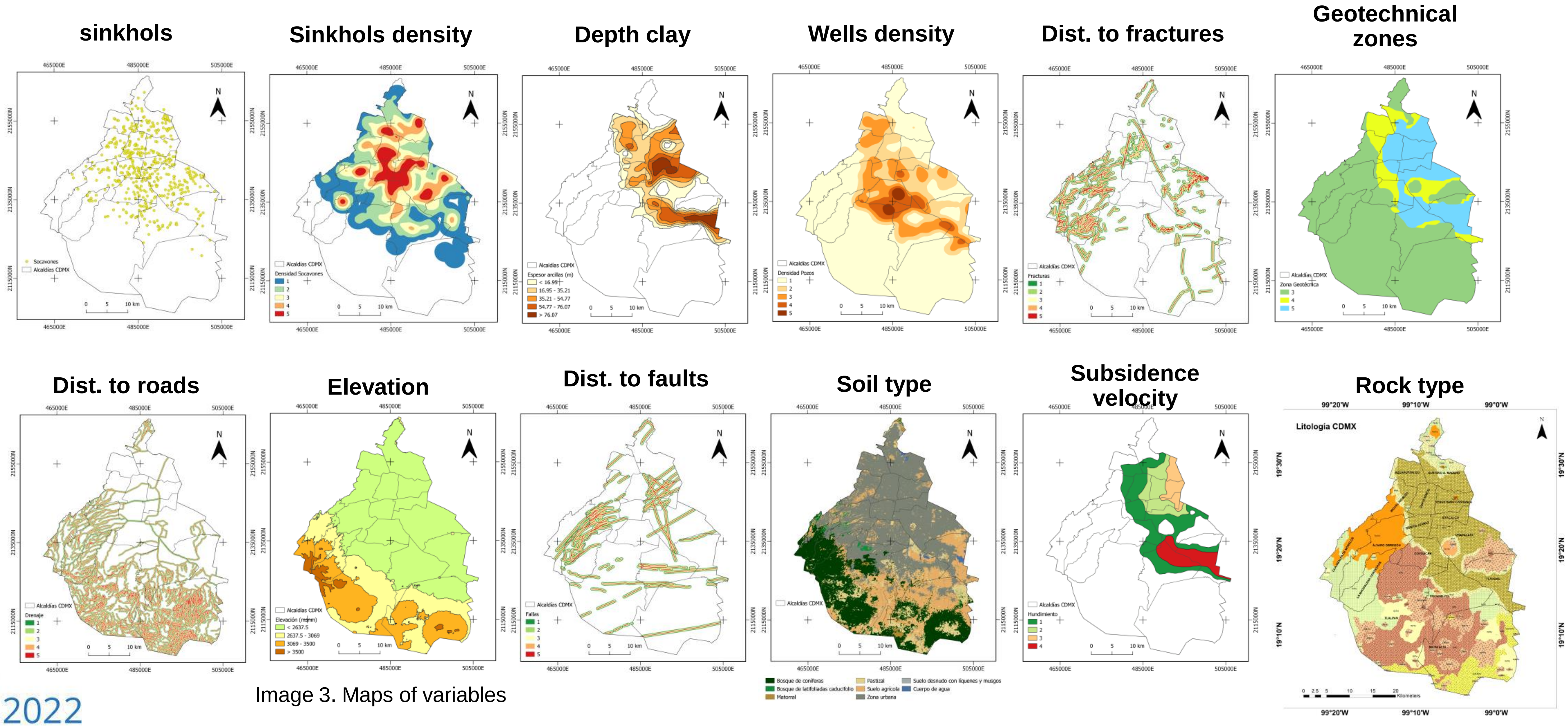

Image 3. Maps of variables

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Results - Exploratory analysis

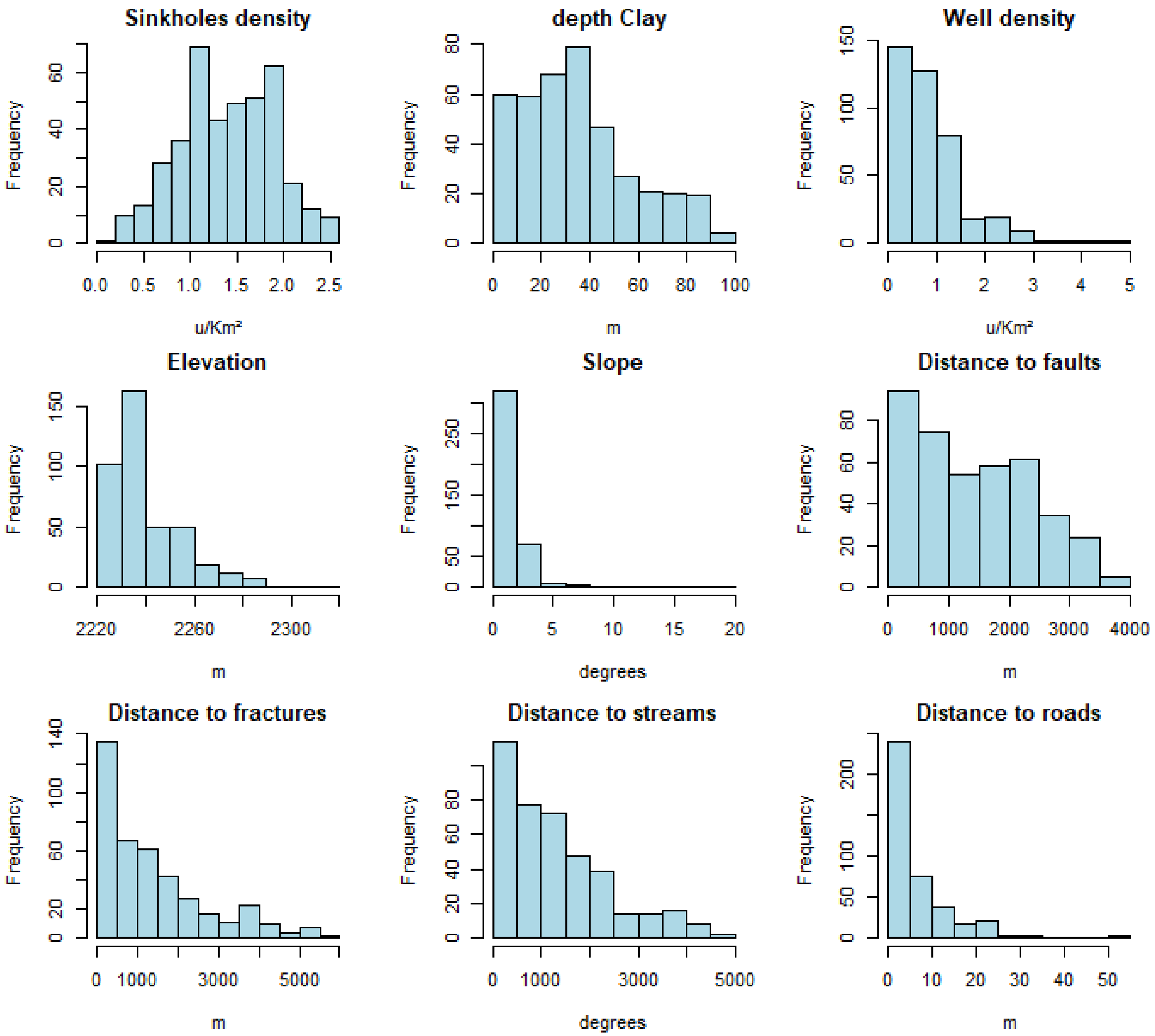

Image 4. Frequency histogram

The only normal distribution is in the density of sinkholes.

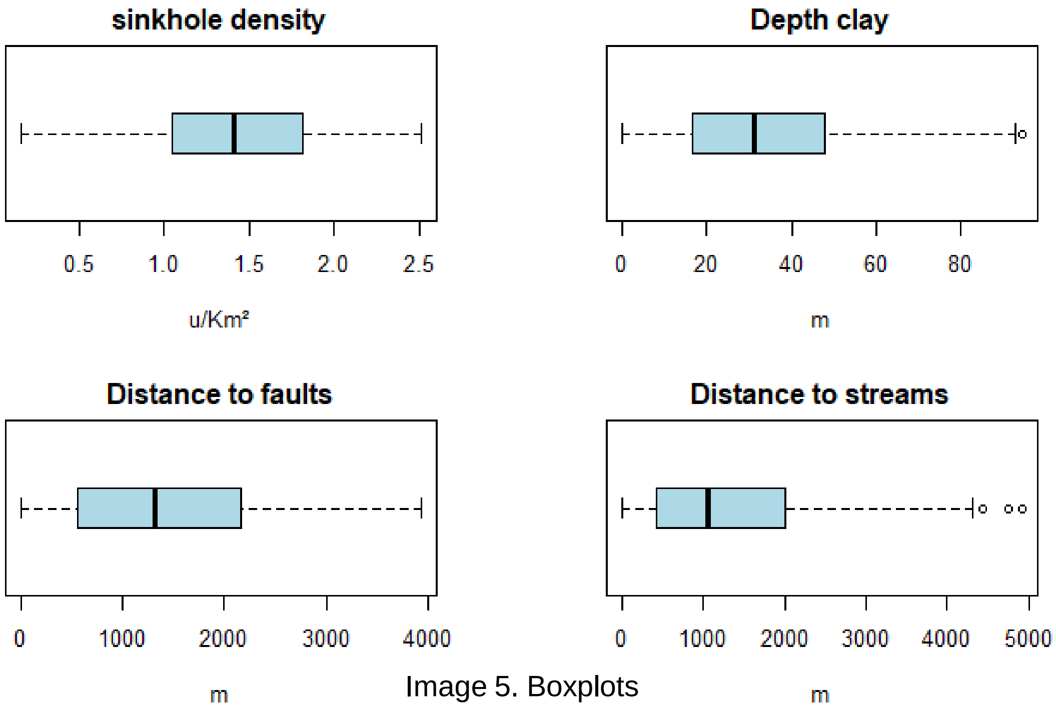

Image 5. Boxplots

Outliers were sought in the data for sinkhole density, clay thickness, distance to faults and distance to streams, because they could not be observed with the naked eye.

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Results

Most of the reclassified layers show the highest number of sinkholes in one of their classes.

Image 2. Frequency tables

Class	Depth clay (m)	Dist. to streams (m)	Dist. to faults (m)	Dist. to fratures (m)	Dist. to roads (m)	Elevation (m)	Slope (degree)	Population	Wells density	Sinkholes density	Rock type	Soil type	Subsidence vel.	Geotechnical zone
0	0	357	331	284	0	0	0	0	0	0	-	-	68	-
1	102	12	16	23	0	404	321	50	85	1	-	-	201	0
2	133	15	25	26	1	0	77	97	162	23	3	(15) 5	77	0
3	92	9	16	30	7	0	5	101	113	76	1	(17) 399	37	30
4	42	3	11	19	23	0	1	95	33	138	6	-	21	120
5	35	8	5	22	373	0	0	61	11	166	394	-	-	254
Total	404	404	404	404	404	404	404	404	404	404	404	404	404	404

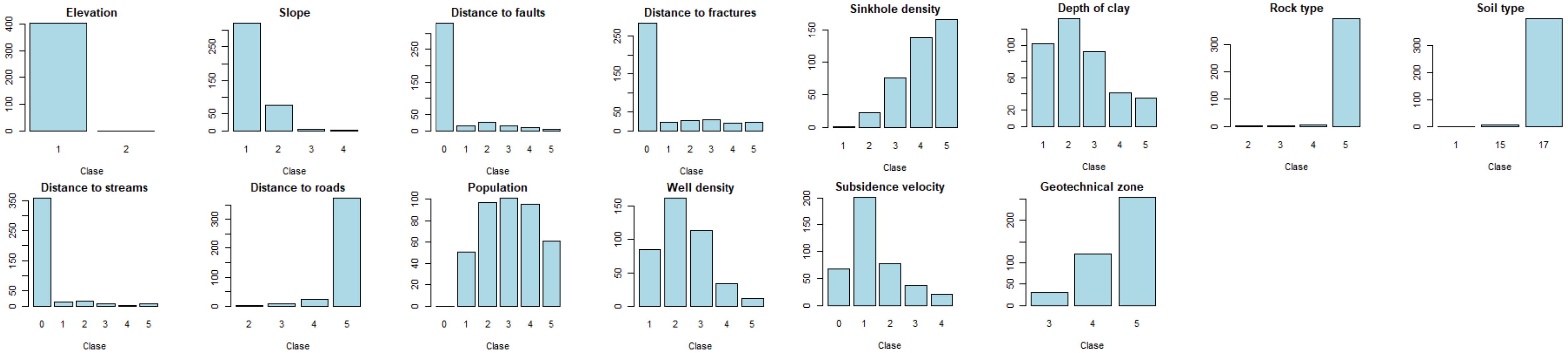

Image 6. Frequency per class

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Results - Chi square test

The most important results of the chi-square test and Cramer's coefficient were obtained for: **Depth of clay, distance to faults, fractures, wells density, subsidence velocity and soil type.**

Table 3. Chi square Test results

	Depth clay	Dist. to streams	Dist. To faults	Dist. a fractures	Dist. to roads	Elevation	Slope	Population	Wells density	Rock type	Soil type	Subsidence velocity	Geotechnical zone
D.F	16	20	20	20	12	0	12	16	16	12	4	16	8
Critical value (0.95)	26.3	31.41	31.41	31.41	21.03	-	21.03	26.3	26.3	21.03	9.49	26.3	15.51
χ^2	27.76	15.78	40.61	35.08	7.22	-	17.69	25.87	47.52	8.07	44.28	55.53	12.899
V	0.13	0.10	**0.16**	**0.15**	0.07	-	0.12	0.13	**0.17**	0.08	**0.33**	**0.19**	0.13

Results - Lineal regression model

The linear regression model was performed with the variables that had a Chi-square value greater than the critical value and greater than 0.15 in Cramer's coefficient.

The model performed with these variables explains 21%.

Table 4. Lineal model regression results

	Intercept	Soil type	Subsidence velocity				Well density				Dist. To faults					Dist. a fractures				
			1	2	3	4	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Estimate	1.18	-0.13	0.29	0.25	0.26	-0.26	0.36	0.24	0.05	0.09	-0.20	0.05	-0.37	-0.44	-0.08	-0.10	-0.09	0.05	-0.17	-0.40
Std. Error	0.22	0.21	0.07	0.09	0.11	0.12	0.07	0.08	0.10	0.16	0.12	0.10	0.12	0.14	0.21	0.10	0.10	0.09	0.11	0.10
t value	5.43	-0.65	4.27	2.89	2.31	-2.17	5.15	3.03	0.45	0.57	-1.67	0.48	-3.03	-3.06	-0.39	-0.94	-0.94	0.55	-1.53	-3.90
Pr(>| t |)	9.93E-08	0.52	2.52E-05	0.00412	0.0213	0.03091	4.24E-07	0.00259	0.65	0.57	0.09488	0.63	0.00259	0.00237	0.70	0.35	0.35	0.58	0.13	0.00011

Residual Std. Error	R^2	R^2 adjusted
0.45	0.25	**0.21**

Conclusions

So far, the correlation analysis applied with the chi-square test identified that the layers: soil, sinkhole velocity, well density, distance to faults and fractures. They have little relationship with the presence of sinkholes in the CDMX. Furthermore, the use of these variables in the linear regression model could only describe 21% of the variability of sinkhole density.

This leads us to believe that there is a non-linear relationship between the variables and sinkholes, so we continue to investigate which other models and which other variables can better describe the presence of sinkholes in the CDMX.

Thanks for your attention

If you have any questions or comments, please send them to my email address

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