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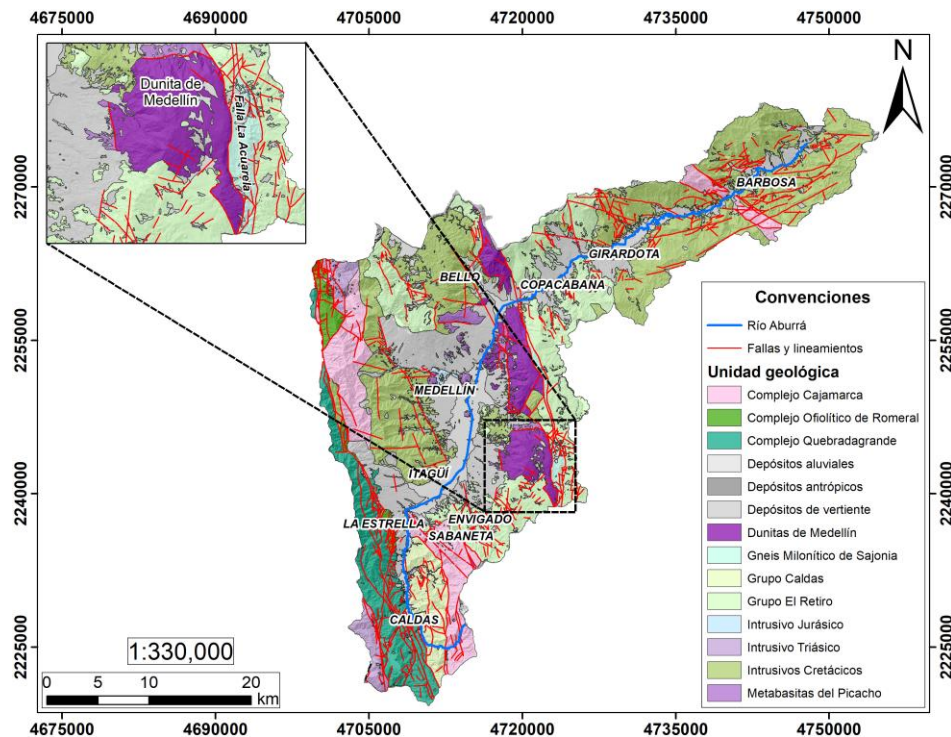
ANÁLISIS ESPACIAL DE LA DISTRIBUCIÓN DE GEOFORMAS KÁRSTICAS EN LA DUNITA DE MEDELLÍN

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Problema de investigación

¿Qué factores controlan la formación y distribución de las geoformas kársticas en la Dunita de Medellín?



Fuente: Elaboración propia.

Fuentes de información

Inventario de geoformas kársticas en la
Dunita de Medellín



Georreferenciación de puntos
inventariados a partir de estudios
reportados en la zona



(Herrera, 2003, Solingral S.A & Alcaldía
de Medellín, 2011)

ANEXO I.

INVENTARIO DE RASGOS CÁRSICOS

CAVERNAS

1	836814.8	1178152.5	6	840006.0	1175660.6	11	840337.8	1178919.9	16	841621.7	1177373.3
2	836903.2	1176033.7	7	840126.5	1178257.5	12	840297.7	1178710.2	17	841259.0	1175977.0
3	836968.2	1176045.1	8	840256.2	1179341.4	13	840405.2	1177728.3	18	841408.5	1178365.9
4	836906.8	1177679.3	9	840281.6	1178466.9	14	840992.5	1179185.1	19	841418.8	1176238.8
5	836949.0	1175988.0	10	840319.4	1178416.3	15	840967.0	1176399.7			

SURGENCIAS

1	836377.0	1179681.1	6	840072.7	1175914.5	11	840263.1	1179221.4	16	840668.3	1176071.1
2	836377.0	1179681.1	7	840079.9	1179547.5	12	840263.1	1179221.5	17	841545.8	1177805.3
3	840071.3	1179350.0	8	840079.9	1179547.6	13	840297.9	1179453.3	18	841545.8	1177805.4
4	840071.3	1179350.0	9	840247.3	1179559.3	14	840297.9	1179453.4			
5	840072.7	1175914.4	10	840247.3	1179559.4	15	840668.3	1176071.0			

COLINAS RESIDUALES

1	836250.0	1176704.9	16	836649.4	1176722.9	31	840269.9	1179108.1	46	840785.3	1176946.7
2	836251.4	1176711.7	17	836690.1	1175963.0	32	840276.3	1175929.9	47	840914.0	1179237.0
3	836270.9	1176658.4	18	83705.1	1176761.5	33	840396.6	1176658.3	48	841007.1	1179139.3
4	836289.0	1176603.0	19	83750.2	1176632.4	34	840427.3	1176673.3	49	841029.5	1179208.5
5	836289.0	1176755.9	20	83727.8	1177369.2	35	840483.7	1176853.6	50	841033.6	1179117.8
6	836336.3	1176605.9	21	83746.7	1176862.9	36	840503.3	1176895.5	51	841089.9	1179740.3
7	836335.9	1176674.2	22	83751.0	1176768.7	37	840527.2	1176907.1	52	841105.2	1176905.5
8	836366.2	1176655.2	23	83750.2	1176739.7	38	840543.1	1176589.0	53	841131.5	1179149.3
9	836406.4	1176593.4	24	83768.1	1176509.1	39	840567.7	1176550.2	54	841190.6	1176905.5
10	836580.5	1176059.8	25	84052.2	1175953.3	40	840587.0	1176462.3	55	841133.5	1179104.6
11	836580.5	1177007.0	26	840104.2	1176120.9	41	840677.0	1176979.5	56	841273.2	1179002.8
12	836603.1	1177875.0	27	840150.1	1176155.2	42	840719.9	1176959.9	57	841304.6	1177954.4
13	836619.7	1176840.6	28	840272.6	1176141.7	43	840750.0	1177000.0	58	841356.7	1176925.0
14	836636.7	1176820.6									

PONORES

1	836611.9	1177516.5	37	836970.5	1176891.7	73	840176.0	1176880.4	110	840432.0	1176840.2
2	836611.9	1177516.5	38	836971.0	1176077.4	74	840183.1	1176806.4	111	840432.0	1176840.2
3	836671.5	1177572.0	39	836974.4	1177640.7	75	840215.8	1176862.9	112	840435.1	1176812.5
4	836671.5	1177572.0	40	836974.4	1177640.7	76	840238.3	1176902.2	113	840435.1	1176812.5
5	836710.0	1176841.0	41	836962.1	1177883.5	77	840244.4	1176835.3	114	840443.8	1177882.8
6	836710.0	1176841.0	42	836962.1	1177883.5	78	840264.4	1176835.3	115	840444.9	1177881.8
7	836723.1	1177948.5	43	836962.1	1177883.5	79	840268.4	1176835.3	116	840444.9	1177881.8
8	836723.1	1177948.5	44	840011.1	1179026.9	80	840284.4	1176827.4	117	840448.9	1179098.1
9	836725.3	1177566.0	45	840024.5	1178966.7	81	840285.4	1179478.4	118	840449.0	1179098.1
10	836725.4	1177566.0	46	840034.6	1178927.2	82	840285.4	1179478.4	119	840451.5	1176927.5
11	836770.0	1177595.4	47	840034.6	1177743.9	83	840293.8	1178377.1	120	840451.5	1176927.5
12	836770.0	1177595.4	48	840035.4	1177743.9	84	840293.8	1178377.1	121	840452.2	1176927.5
13	836776.6	1177665.9	49	840035.4	1177665.9	85	840305.5	1177965.6	122	840452.2	1176927.5
14	836776.6	1177665.9	50	840048.1	1178825.8	86	840305.5	1177965.6	123	840460.1	1176831.4

Fuentes de información

AMVA → Modelo de elevación digital → Pendientes → Índice de humedad topográfica (TWI)

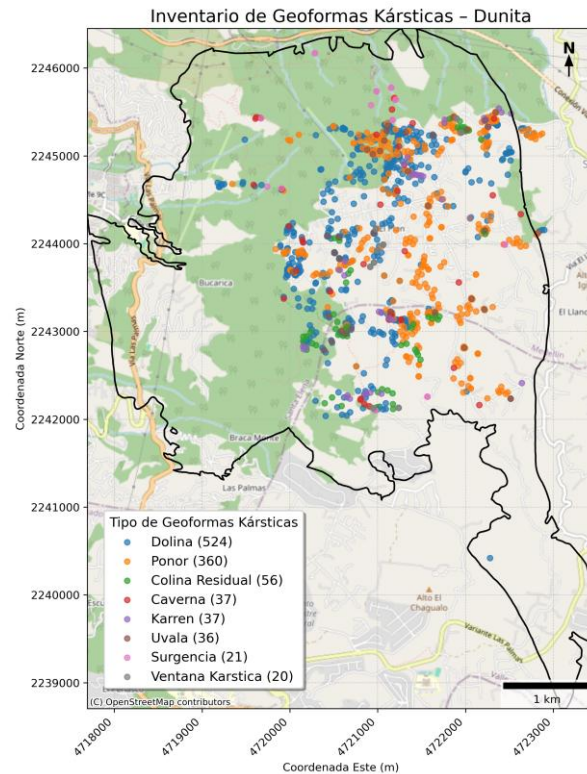
POMCAS Río Aburrá y Río Negro → Cobertura de suelo

POT Municipios de Medellín y Envigado → Red de drenaje

Estudio de microzonificación sísmica (AMVA) y estudio de análisis hidroestructural (Patiño et al., 2021) → Trazo de fallas y lineamientos

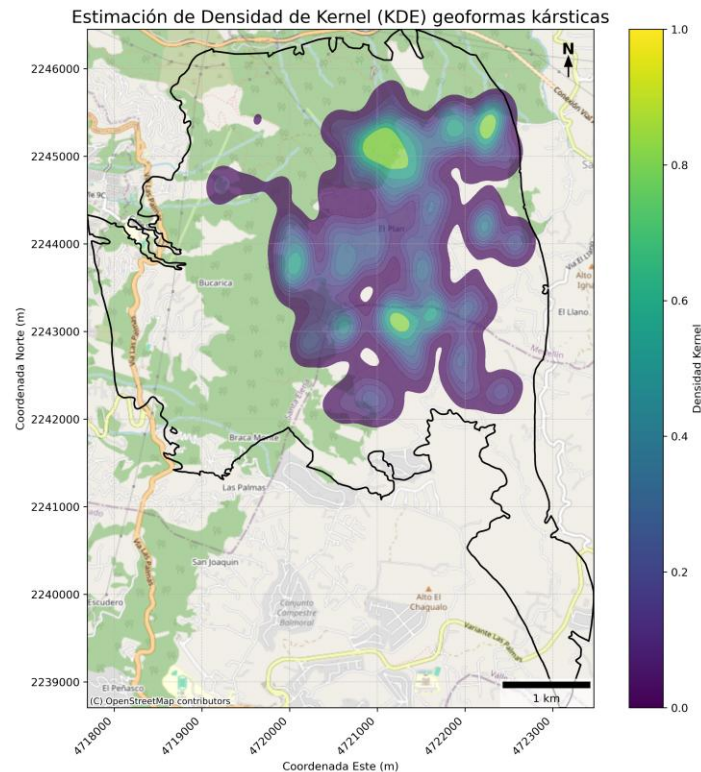
Análisis de patrones de puntos

Visualización



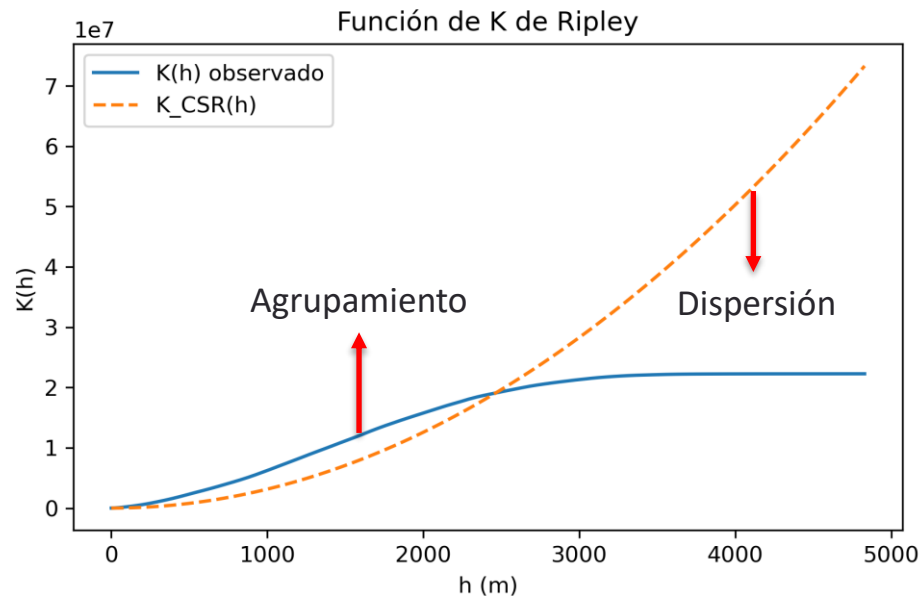
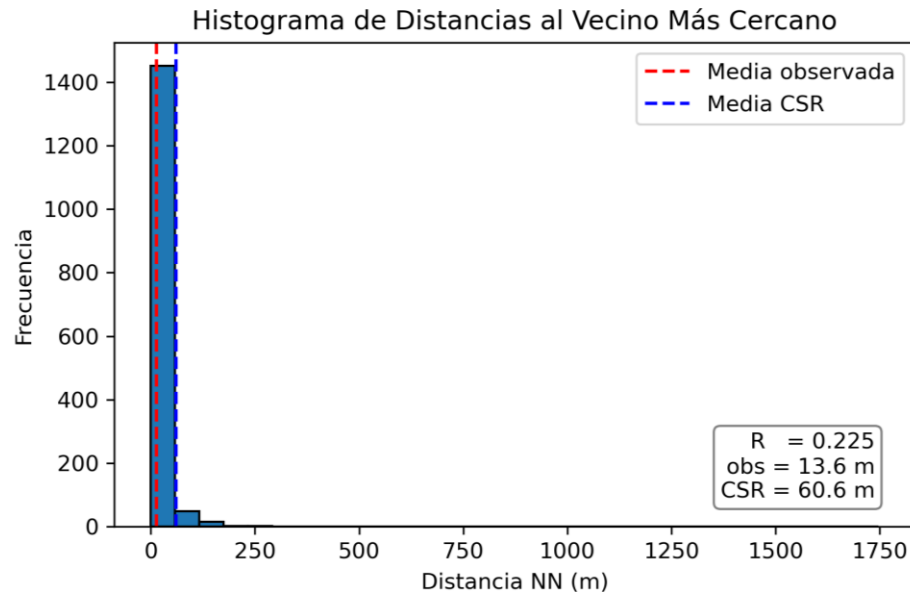
Análisis de patrones de puntos

Métodos basados
en densidad



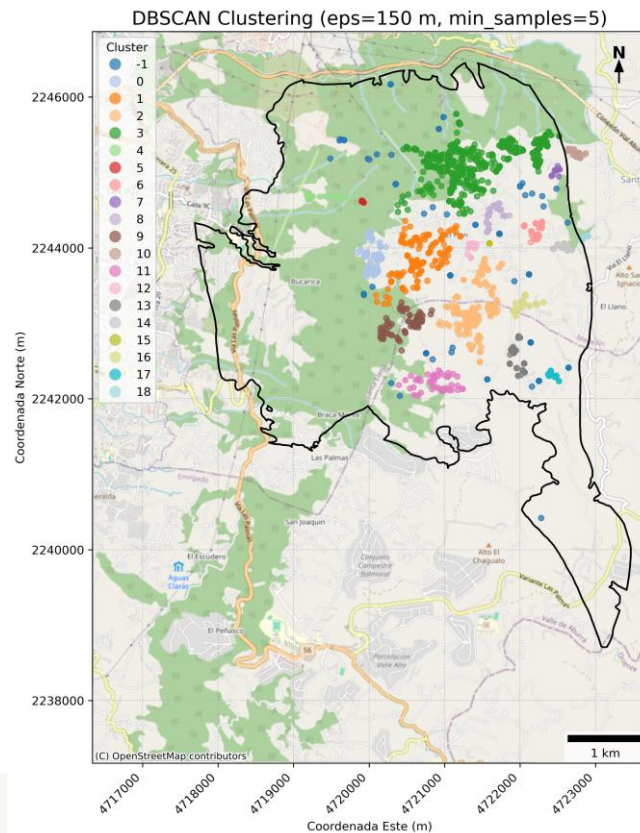
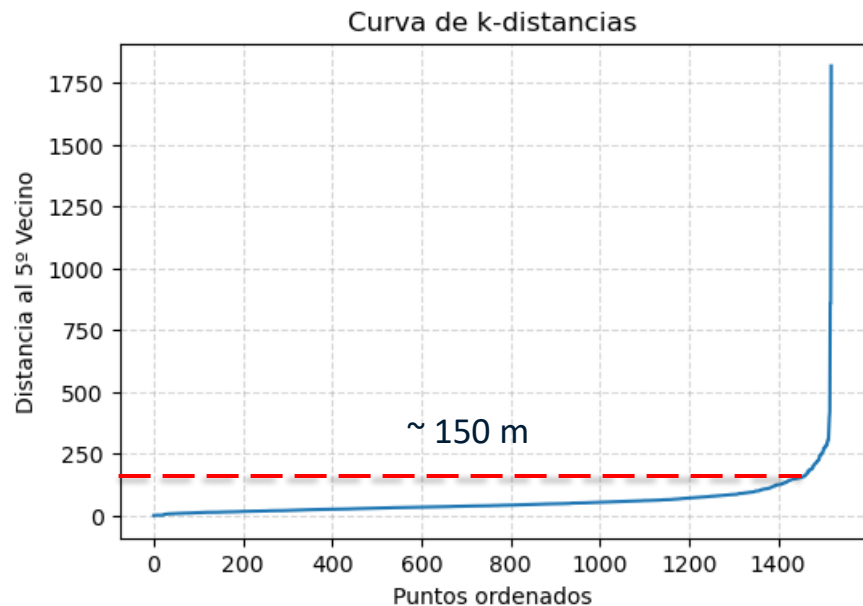
Análisis de patrones de puntos

Métodos basados en distancia



Análisis de patrones de puntos

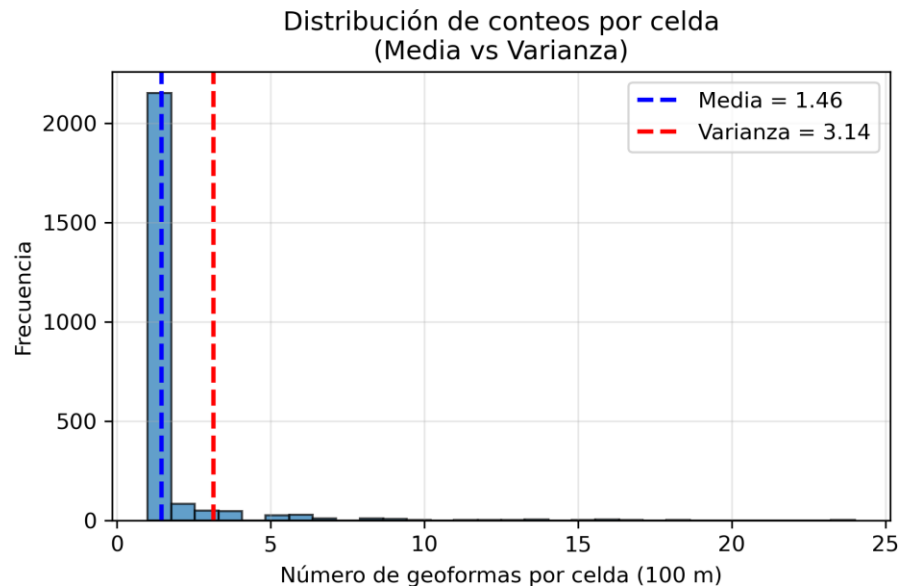
Clustering



Modelo lineal generalizado (GML)

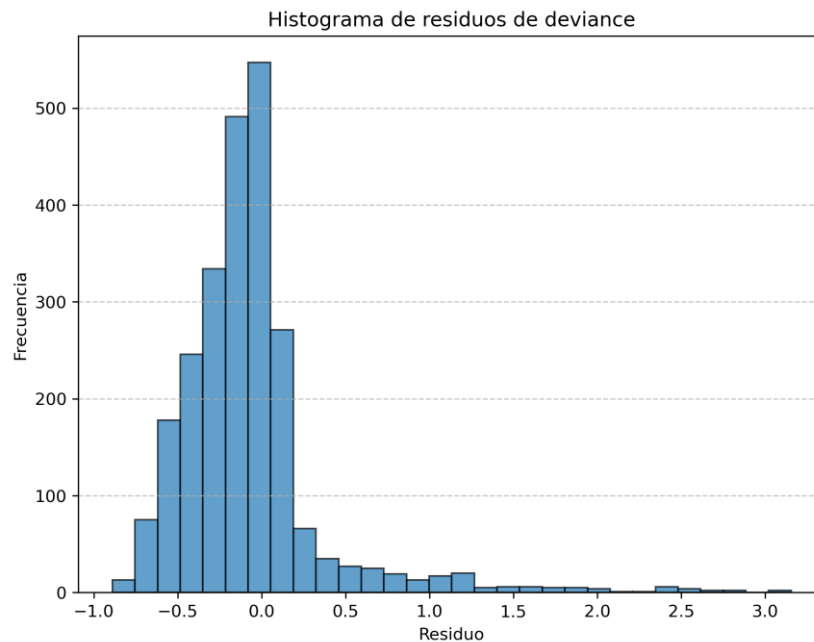
Regresión Binomial Negativa

Este modelo se utiliza cuando la variable dependiente es un conteo de eventos, pero hay sobredispersión (la varianza es mayor que la media)



Modelo lineal generalizado (GML)

Regresión Binomial Negativa

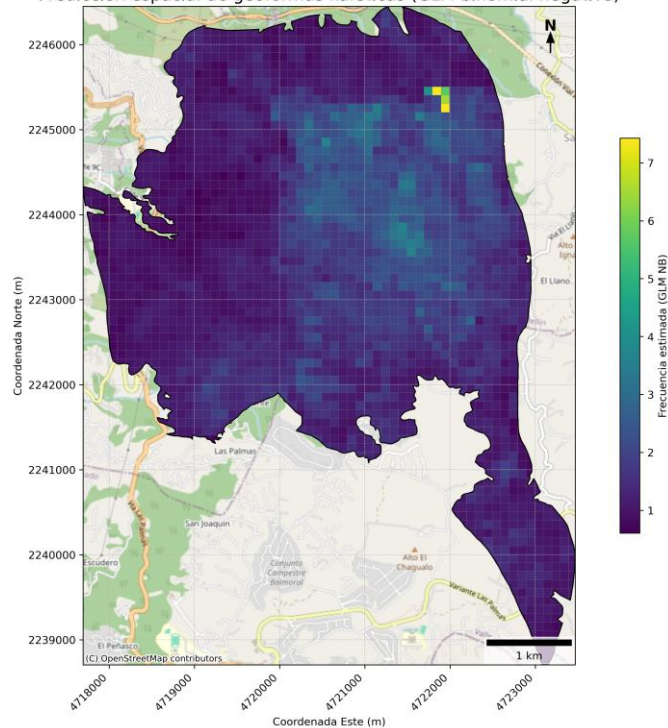


Modelo lineal generalizado (GML)

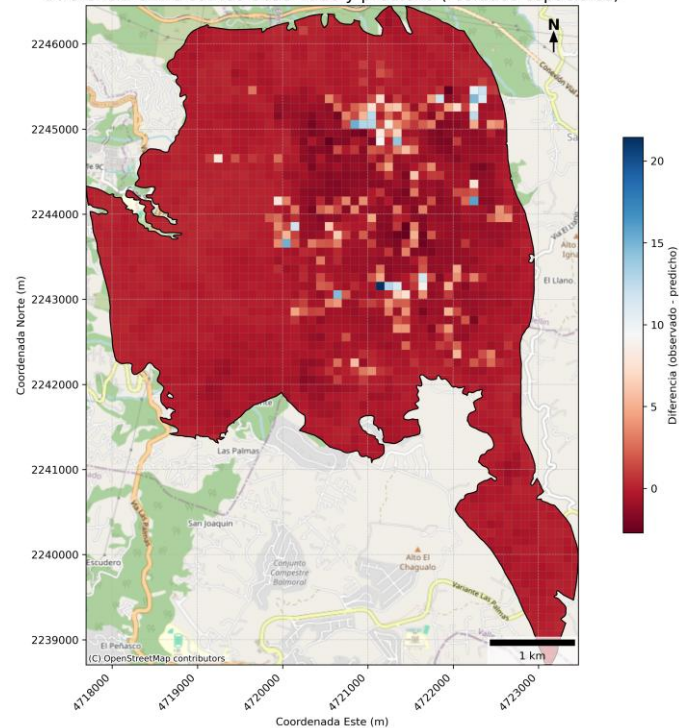
	coef	std err	z	P> z	[0.025	0.975]
const	-1.6993	0.560	-3.033	0.002	-2.797	-0.601
dem_mean	0.0005	0.000	2.806	0.005	0.000	0.001
slope_mean	-0.0146	0.005	-3.201	0.001	-0.024	-0.006
twi_mean	0.1209	0.045	2.665	0.008	0.032	0.210
dist_drain	0.0009	0.000	3.222	0.001	0.000	0.001
dist_fault	0.0003	0.000	2.968	0.003	0.000	0.001
cov_Bosque de galería y/o ripario	0.1050	0.284	0.370	0.711	-0.451	0.661
cov_Bosque fragmentado	0.5021	0.232	2.160	0.031	0.046	0.958
cov_Cereales	0.0941	0.670	0.141	0.888	-1.219	1.407
cov_Cultivos confinados	-0.4945	1.432	-0.345	0.730	-3.301	2.312
cov_Cultivos permanentes arbustivos	0.0774	0.354	0.219	0.827	-0.617	0.771
cov_Mosaico de cultivos	0.0480	0.328	0.146	0.884	-0.594	0.690
cov_Mosaico de cultivos y espacios naturales	1.4833	0.532	2.788	0.005	0.441	2.526
cov_Mosaico de pastos y cultivos	0.3901	0.303	1.287	0.198	-0.204	0.984
cov_None	0.1992	0.402	0.496	0.620	-0.588	0.986
cov_Otros cultivos transitorios	-0.1487	1.432	-0.104	0.917	-2.955	2.657
cov_Pastos arbolados	-0.0051	0.578	-0.009	0.993	-1.138	1.128
cov_Pastos enmalezados	0.2126	0.269	0.791	0.429	-0.314	0.739
cov_Pastos limpios	0.0868	0.229	0.379	0.704	-0.361	0.535
cov_Plantación forestal	0.5049	0.333	1.518	0.129	-0.147	1.157
cov_Red vial, ferroviaria y terrenos asociados	0.0314	1.024	0.031	0.976	-1.976	2.039
cov_Tejido urbano continuo	0.4188	0.294	1.424	0.154	-0.158	0.995
cov_Tejido urbano discontinuo	0.3088	0.233	1.325	0.185	-0.148	0.765
cov_Tierras desnudas y degradadas	0.4709	0.536	0.879	0.379	-0.579	1.521
cov_Vegetación secundaria o en transición	0.3810	0.227	1.681	0.093	-0.063	0.825
cov_Zonas verdes urbanas	0.3033	0.283	1.073	0.283	-0.251	0.858

Modelo lineal generalizado (GML)

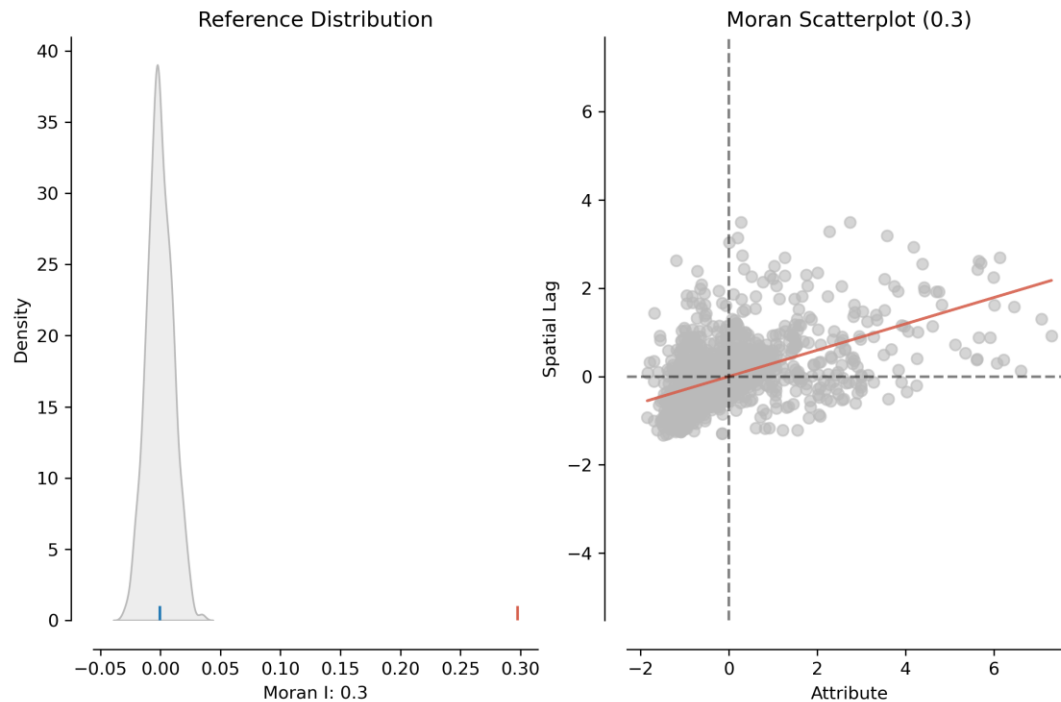
Predicción espacial de geoformas kársticas (GLM binomial negativo)



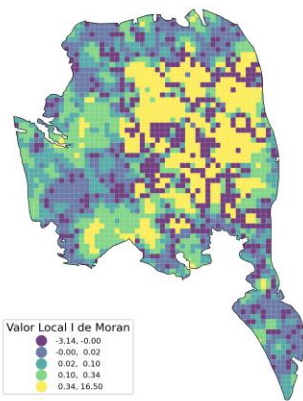
Diferencia entre conteo observado y predicho (residuos espaciales)



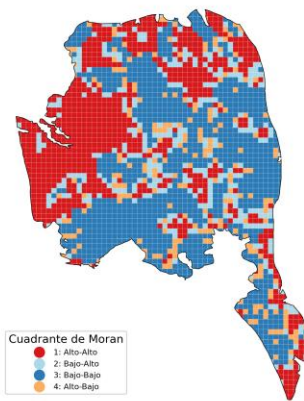
Autocorrelación espacial global



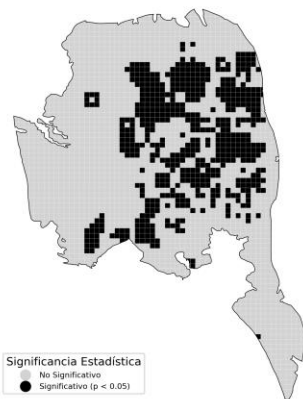
Valores de I de Moran Local ('Is')



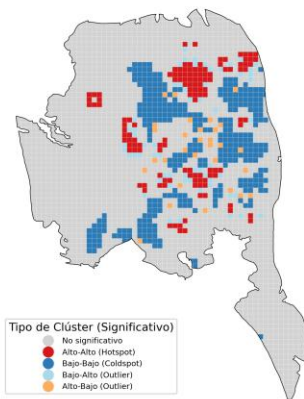
Cuadrantes de Moran (Sin Filtro de Significancia)



Mapa de Significancia de LISA

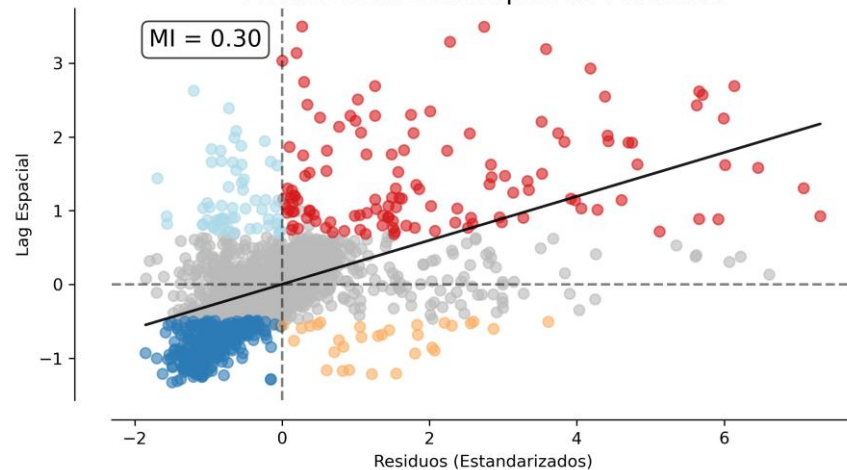


Mapa de Clústeres LISA (Significativos)

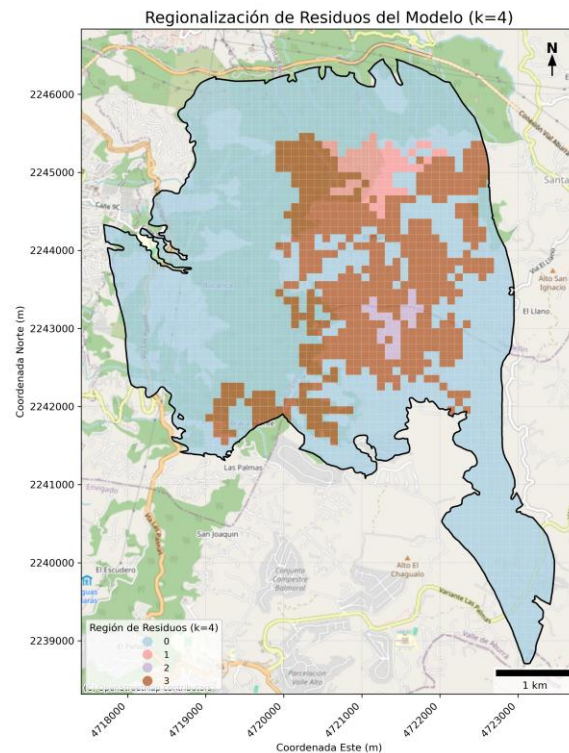
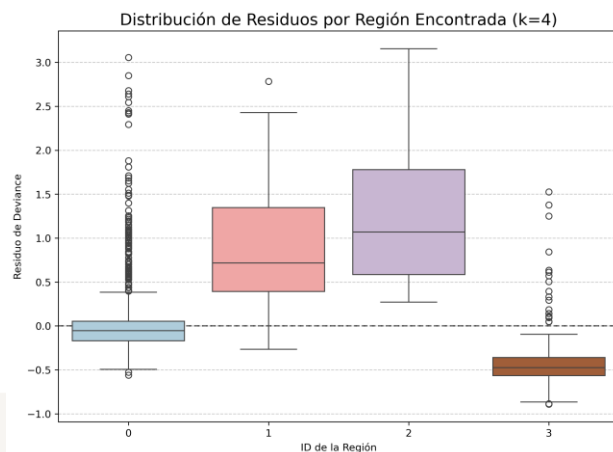
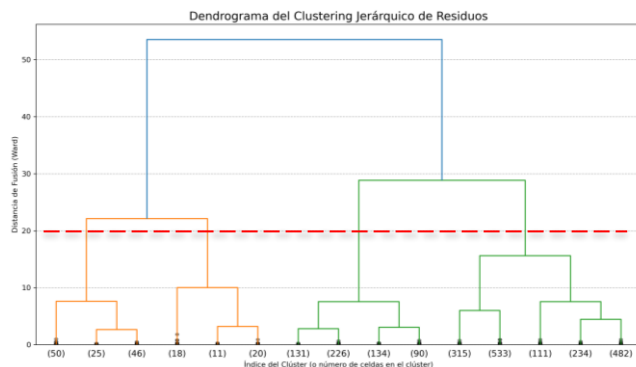


Autocorrelación espacial local

Moran Local Scatterplot de Residuos



Agrupamiento espacial (Regionalización)



Modelo de regresión para dependencia espacial tipo SAR

REGRESSION RESULTS

SUMMARY OF OUTPUT: MAXIMUM LIKELIHOOD SPATIAL LAG (METHOD = FULL)

```

Data set      : unknown
Weights matrix : Queen
Dependent Variable : count
Mean dependent var : 1.4596
S.D. dependent var : 1.7774
Pseudo R-squared : 0.2938
Spatial Pseudo R-squared: 0.1093
Log likelihood : -4496.4363
Sigma-square ML : 2.2615
S.E of regression : 1.5038

Number of Observations: 2426
Number of Variables : 9
Degrees of Freedom : 2417

Akaike info criterion : 9010.873
Schwarz criterion : 9063.019

```

Variable	Coefficient	Std.Error	z-Statistic	Probability
CONSTANT	-0.50299	0.48702	-1.03279	0.30170
dem_mean	0.00005	0.00016	0.31294	0.75432
slope_mean	-0.00721	0.00461	-1.56289	0.11808
twi_mean	0.18486	0.05126	3.60627	0.00031
dist_drain	0.00069	0.00033	2.08630	0.03695
dist_fault	0.00031	0.00012	2.60648	0.00915
cov_Bosque fragmentado	0.12416	0.08696	1.42782	0.15334
cov_Mosaico de cultivos y espacios naturales	2.90879	0.67620	4.30166	0.00002
W_count	0.55960	0.02512	22.27575	0.00000

SPATIAL LAG MODEL IMPACTS

Impacts computed using the 'simple' method.

Variable	Direct	Indirect	Total
dem_mean	0.0000	0.0001	0.0001
slope_mean	-0.0072	-0.0092	-0.0164
twi_mean	0.1849	0.2349	0.4197
dist_drain	0.0007	0.0009	0.0016
dist_fault	0.0003	0.0004	0.0007
cov_Bosque fragmentado	0.1242	0.1578	0.2819
cov_Mosaico de cultivos y espacios naturales	2.9088	3.6961	6.6049

===== END OF REPORT =====

Regresión Ponderada Geográficamente Multiescala (MGWR)

Multi-Scale Geographically Weighted Regression (MGWR) Results

Spatial kernel: Adaptive bisquare
 Criterion for optimal bandwidth: AICc
 Score of Change (SOC) type: Smoothing f
 Termination criterion for MGWR: 1e-05

MGWR bandwidths

Variable	Bandwidth	ENP_j	Adj t-val(95%)	Adj alpha(95%)
X0	2425.000	1.085	1.996	0.046
X1	2425.000	1.077	1.992	0.046
X2	2425.000	1.133	2.014	0.044
X3	45.000	140.838	3.577	0.000
X4	213.000	23.344	3.073	0.002
X5	61.000	86.769	3.447	0.001
X6	2425.000	1.065	1.988	0.047
X7	2363.000	1.002	1.962	0.050

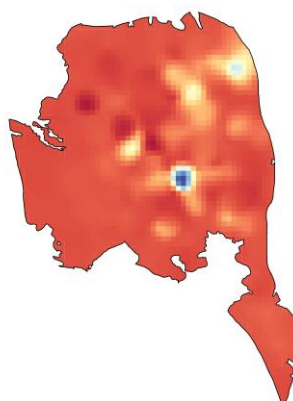
Diagnostic information

Residual sum of squares:	3907.046
Effective number of parameters (trace(S)):	256.313
Degree of freedom (n - trace(S)):	2169.687
Sigma estimate:	1.342
Log-likelihood:	-4020.385
AIC:	8555.396
AICc:	8616.722
BIC:	10046.268
R2	0.490
Adjusted R2	0.430

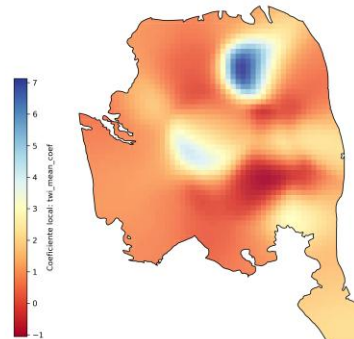
Summary Statistics For MGWR Parameter Estimates

Variable	Mean	STD	Min	Median	Max
X0	1.269	0.014	1.238	1.274	1.284
X1	0.173	0.009	0.149	0.176	0.186
X2	-0.134	0.006	-0.138	-0.137	-0.114
X3	0.193	0.691	-1.052	-0.009	7.128
X4	0.050	0.185	-0.349	-0.000	1.003
X5	0.040	0.605	-3.661	0.016	3.765
X6	0.089	0.007	0.081	0.085	0.110
X7	0.096	0.007	0.089	0.092	0.125

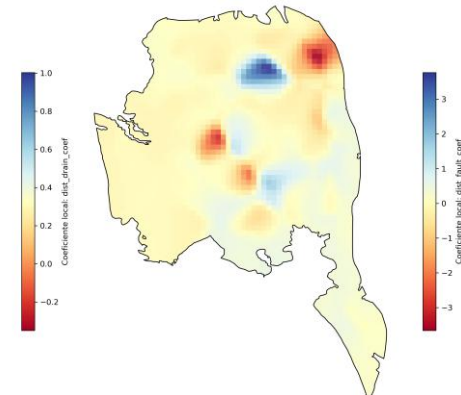
MGWR - Coeficientes Locales de twi_mean_coef



MGWR - Coeficientes Locales de dist_drain_coef



MGWR - Coeficientes Locales de dist_fault_coef



Gracias

Universidad Nacional de Colombia
