UNIVERSIDAD
NACIONAL
DE COLOMBIA

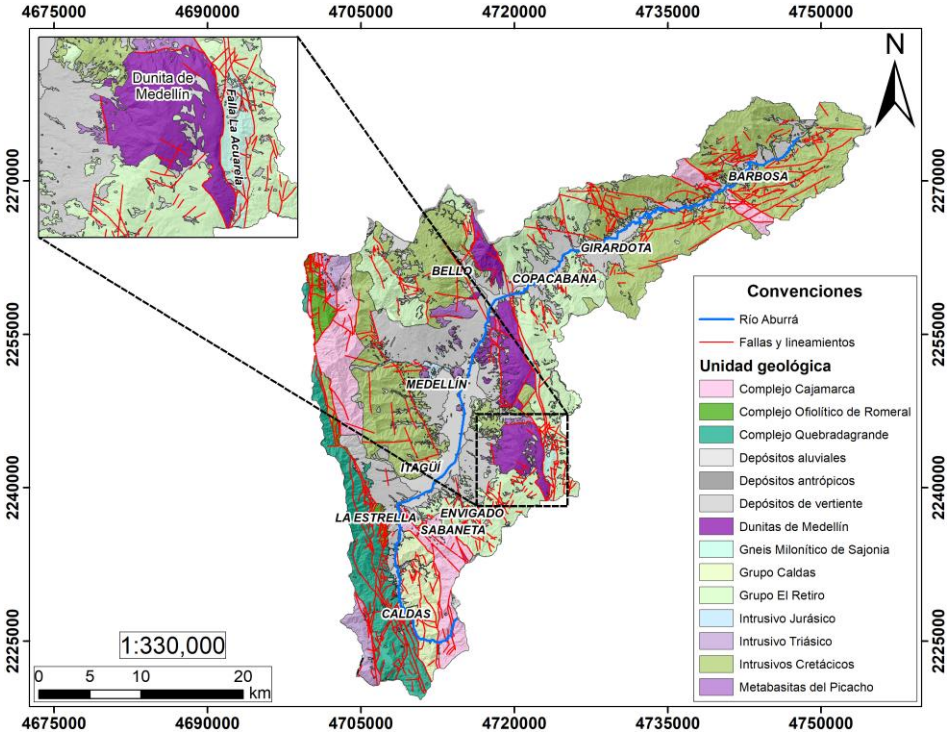
ANÁLISIS ESPACIAL DE LA DISTRIBUCIÓN DE GEOFORMAS KÁRSTICAS EN LA DUNITA DE MEDELLÍN

Juan Esteban Montoya Moreno

Facultad de Minas – Departamento de Geociencias y Medio Ambiente - Sede Medellín

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	839814.8	1176152.5	6	840006.9	1175960.6	11	840337.8	1178919.9	16	841021.7	1177373.3
2	839903.2	1176033.7	7	840126.5	1178257.5	12	840397.7	1178710.2	17	841259.0	1175977.0
3	839908.2	1176045.7	8	840256.2	1179341.4	13	840405.2	1177728.3	18	841406.5	1178365.9
4	839936.8	1177579.3	9	840281.8	1179466.9	14	840492.5	1179185.1	19	841418.8	1179238.8
5	839949.0	1175988.0	10	840319.4	1178416.3	15	840967.0	1176399.7			

SURGENCIAS

1	839377.0	1179981.1	6	840072.7	1175914.5	11	840263.1	1179221.4	16	840666.3	1176071.1
2	839377.0	1179981.2	7	840078.9	1179547.5	12	840263.1	1179221.5	17	841545.6	1177805.3
3	840017.3	1179390.9	8	840079.9	1179547.6	13	840297.9	1179453.3	18	841545.6	1177805.4
4	840017.3	1179390.0	9	840247.3	1179589.3	14	840297.9	1179453.4			
5	840072.7	1175914.4	10	840247.3	1179589.4	15	840666.3	1176071.0			

COLINAS RESIDUALES

1	839250.0	1176704.5	15	839649.4	1176772.6	29	840299.9	1176108.1	43	840785.3	1176948.7
2	839251.4	1176751.7	16	839660.3	1177845.7	30	840273.7	1175984.7	44	840802.1	1176885.1
3	839270.9	1176636.4	17	839690.1	1175963.0	31	840276.3	1175929.9	45	840914.0	1179237.0
4	839289.0	1176603.0	18	839705.1	1176761.5	32	840366.6	1176658.3	46	841007.1	1179139.3
5	839289.0	1176755.9	19	839730.2	1176832.4	33	840427.3	1176673.3	47	841029.5	1179208.5
6	839336.3	1176805.9	20	839737.8	1177369.2	34	840483.7	1176853.6	48	841033.6	1179111.8
7	839353.1	1176674.2	21	839748.7	1176860.9	35	840503.3	1176895.5	49	841049.9	1179140.3
8	839398.2	1176655.2	22	839751.0	1176758.7	36	840527.2	1176607.1	50	841064.2	1179095.5
9	839496.4	1175993.6	23	839782.5	1177470.7	37	840543.1	1176580.0	51	841081.5	1179140.3
10	839580.5	1176059.8	24	839789.1	1177509.1	38	840557.1	1176550.2	52	841096.8	1179095.5
11	839594.6	1177007.0	25	840092.8	1175950.3	39	840587.0	1176492.3	53	841133.5	1179104.6
12	839603.1	1177875.0	26	840104.2	1176120.9	40	840677.0	1176979.5	54	841273.2	1179002.8
13	839619.7	1176840.6	27	840150.1	1176155.2	41	840719.9	1176959.9	55	841304.6	1177954.4
14	839638.7	1176920.6	28	840212.6	1176141.2	42	840750.7	1177000.0	56	841320.7	1177925.0

PONORES

1	839651.9	1177516.5	37	839970.5	1178891.7	73	840178.0	1178980.4	110	840432.0	1178640.2
2	839651.9	1177516.5	38	839971.0	1179077.4	74	840183.1	1178806.4	111	840432.0	1178640.2
3	839671.5	1177572.0	39	839974.4	1177640.7	75	840215.6	1178962.9	112	840435.1	1178812.5
4	839671.5	1177572.0	40	839974.4	1177640.7	76	840218.5	1178790.2	113	840435.1	1178812.5
5	839710.0	1176841.0	41	839982.1	1177883.5	77	840224.4	1178385.3	114	840443.8	1177682.8
6	839710.0	1176841.0	42	839982.1	1177883.5	78	840224.4	1178385.3	115	840444.9	1177681.8
7	839723.1	1177948.5	43	839982.1	1178875.4	79	840238.6	1178893.2	116	840444.9	1177681.8
8	839723.1	1177948.5	44	840011.1	1179026.9	80	840264.4	1178827.4	117	840448.9	1179098.1
9	839725.3	1177566.0	45	840024.5	1178966.7	81	840285.4	1179478.4	118	840449.0	1179098.1
10	839725.4	1177566.0	46	840034.6	1178827.2	82	840285.4	1179478.4	119	840453.5	1176467.3
11	839770.0	1177595.4	47	840035.4	1177743.9	83	840293.6	1178377.1	120	840454.3	1177835.6
12	839770.0	1177595.4	48	840035.4	1177743.9	84	840293.6	1178377.1	121	840455.2	1178787.6
13	839776.6	1178565.9	49	840036.5	1177842.1	85	840305.5	1177965.6	122	840455.2	1178787.6
14	839776.6	1178565.9	50	840048.1	1178825.8	86	840305.5	1177965.6	123	840460.1	1178631.4

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Fuentes de información

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

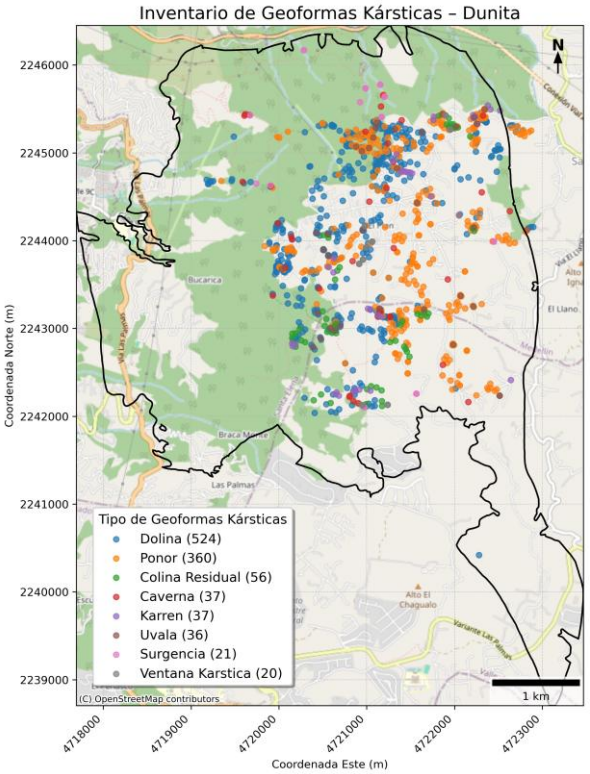
POMCAS Río Aburrá y Río Negro → Cobertura de suelo

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

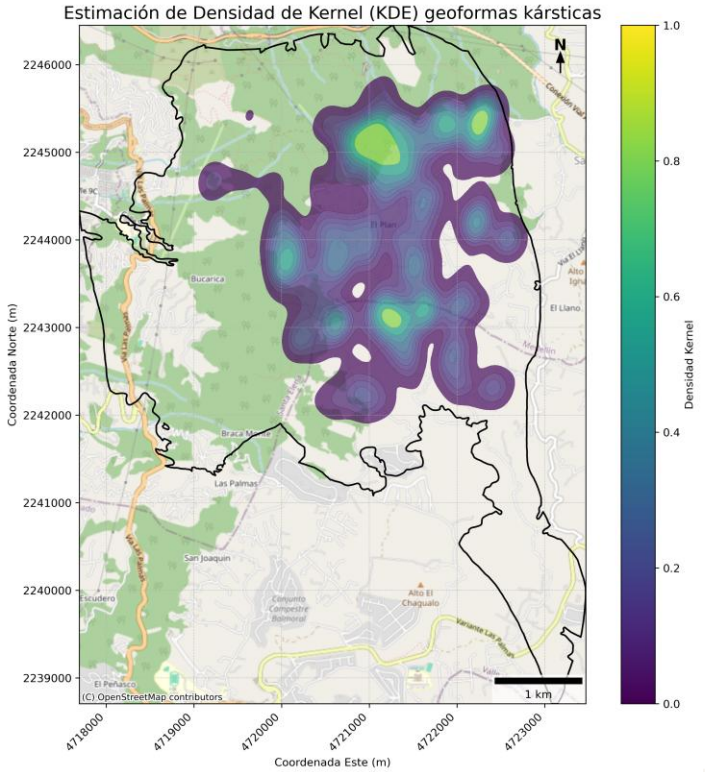
Análisis de patrones de puntos

Visualización



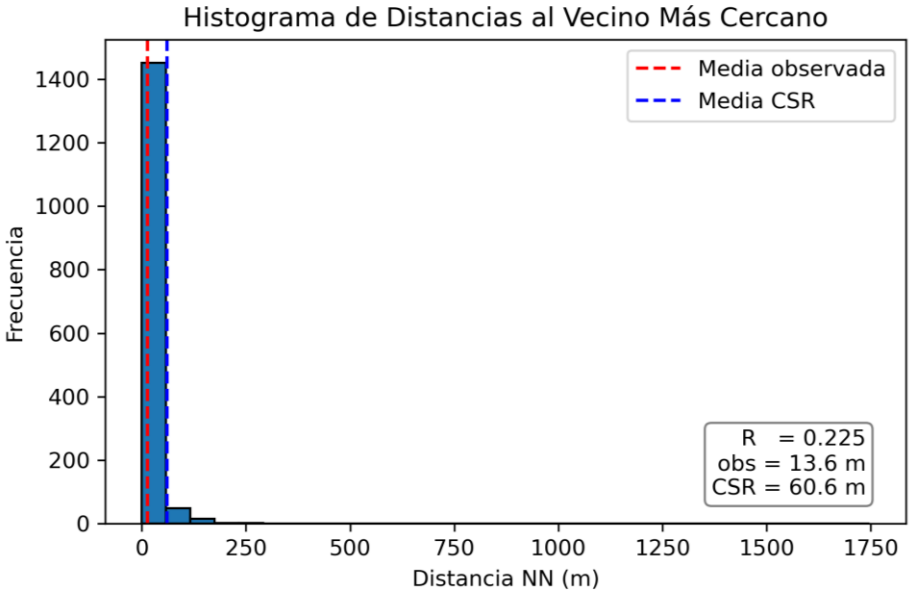
Análisis de patrones de puntos

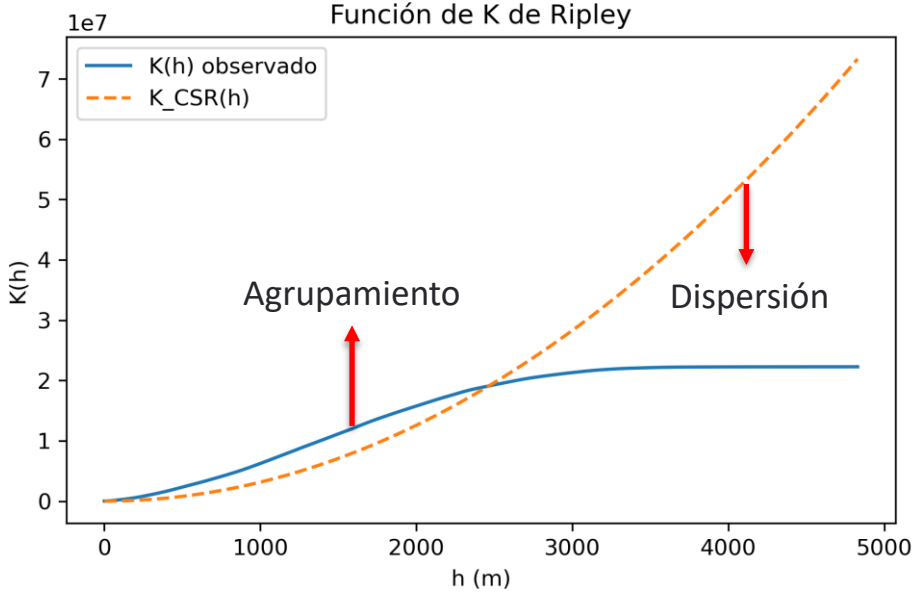
Métodos basados en densidad



Análisis de patrones de puntos

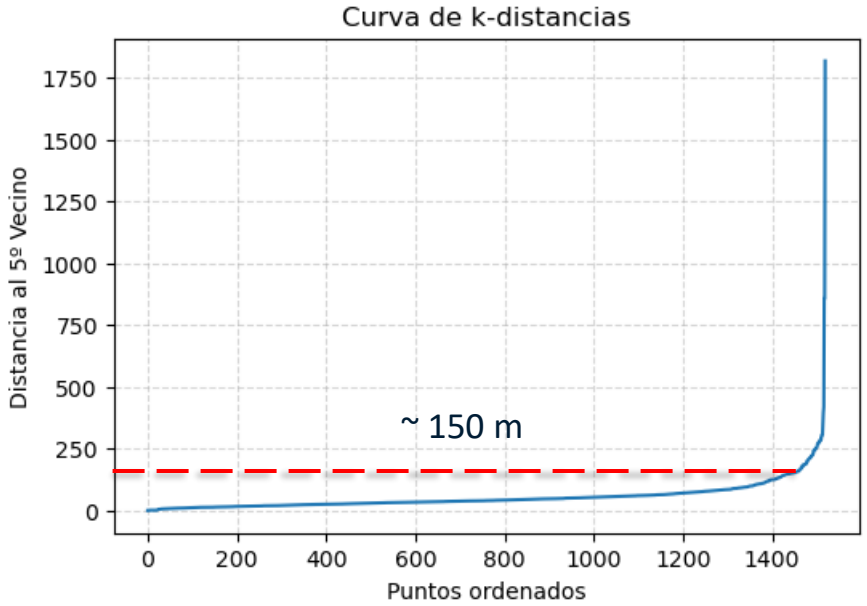
Métodos basados en distancia

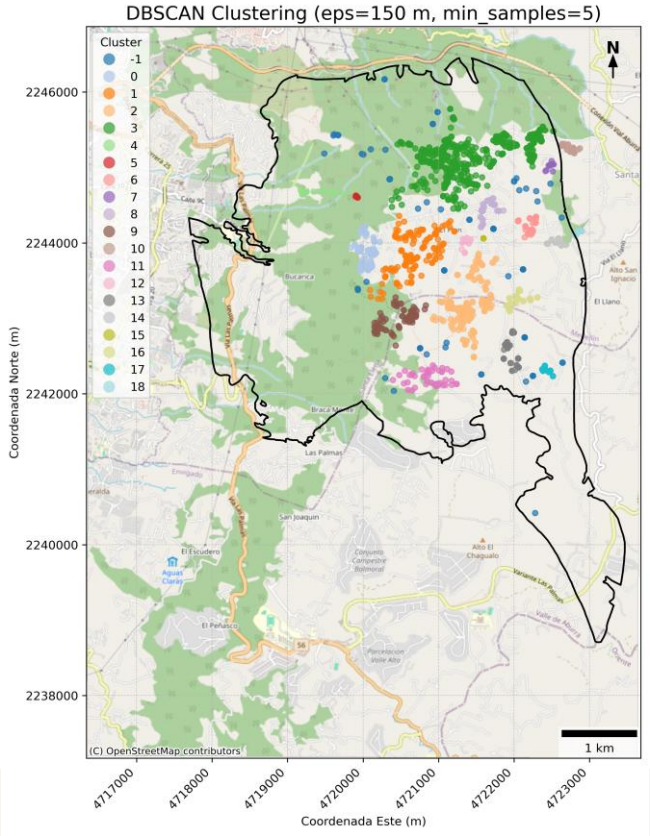




Análisis de patrones de puntos

Clustering

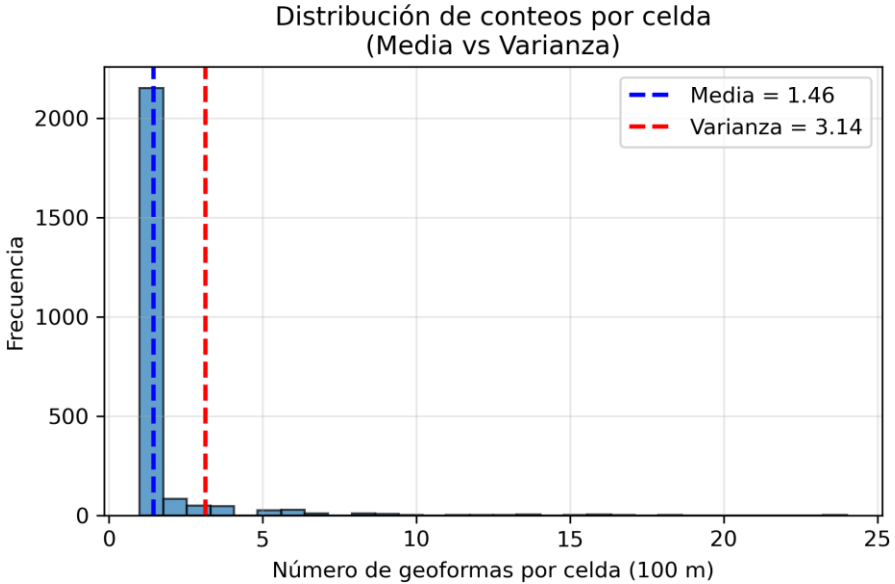




Modelo lineal generalizado (GML)

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)

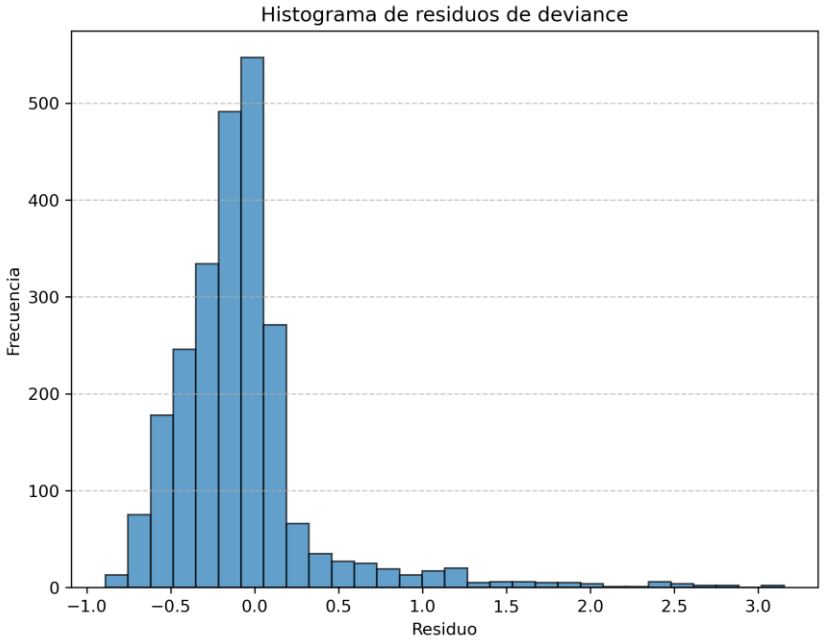


Modelo lineal generalizado (GML)

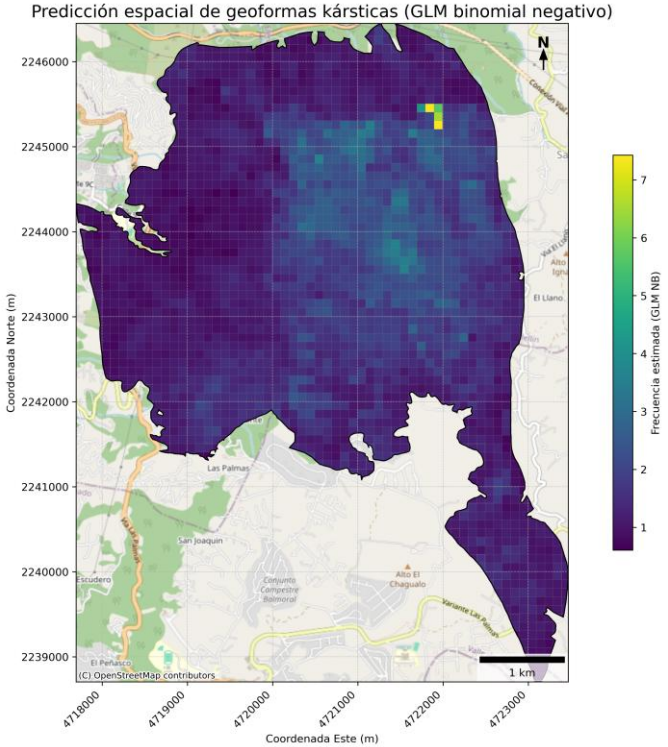
	coef	std err	z	P>|z|	[0.025	0.975]
const	-1.6993	0.560	-3.033	0.002	-2.797	-0.601
dem_mean	0.0005	0.000	2.806	0.005	0.000	0.001
slope_mean	-0.0146	0.005	-3.201	0.001	-0.024	-0.006
twi_mean	0.1209	0.045	2.665	0.008	0.032	0.210
dist_drain	0.0009	0.000	3.222	0.001	0.000	0.001
dist_fault	0.0003	0.000	2.968	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

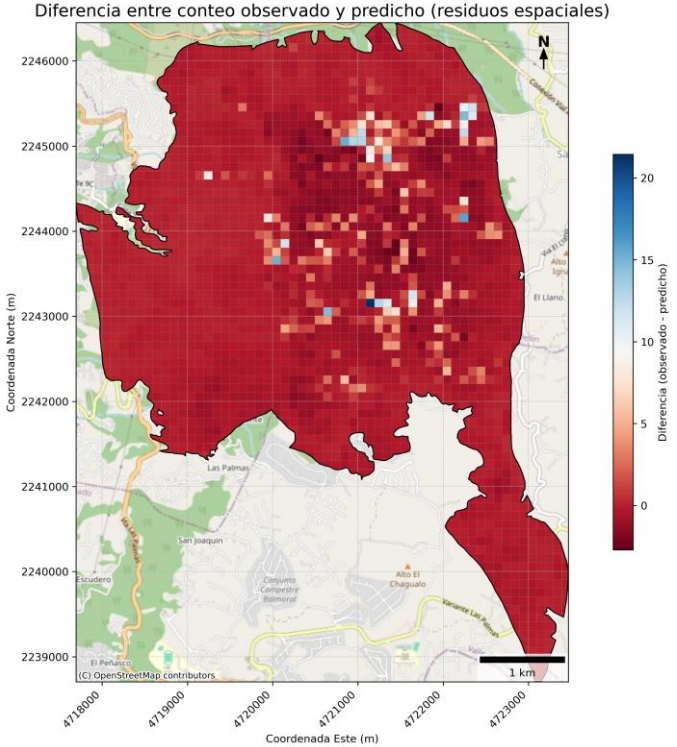
Modelo lineal generalizado (GML)

Regresión Binomial Negativa

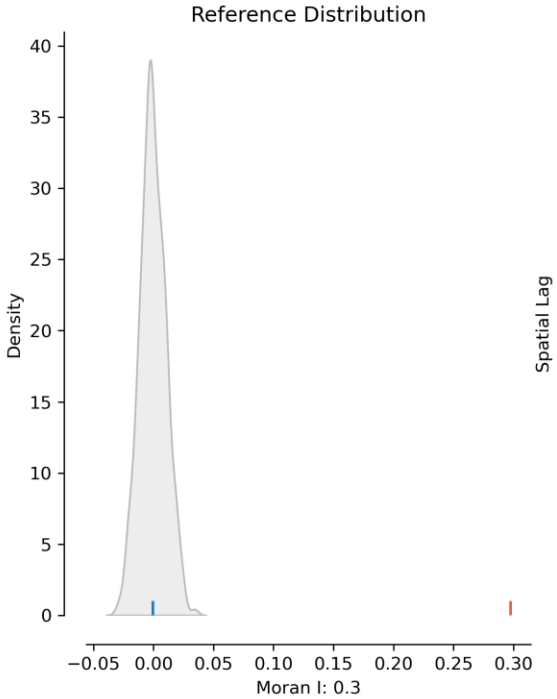


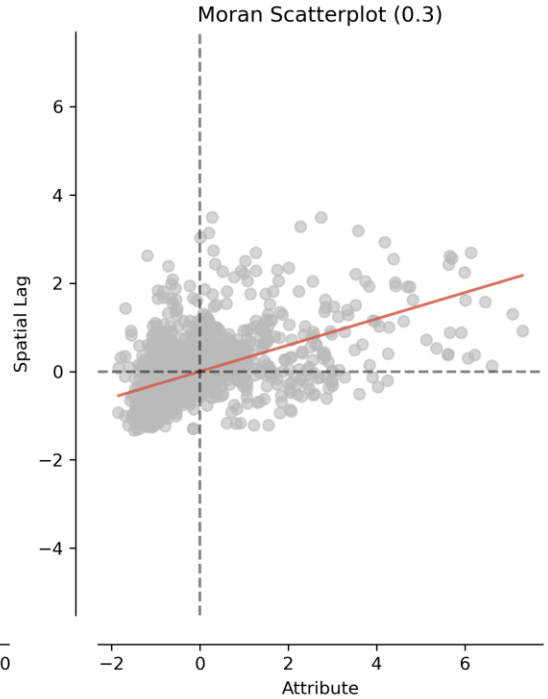
Modelo lineal generalizado (GML)



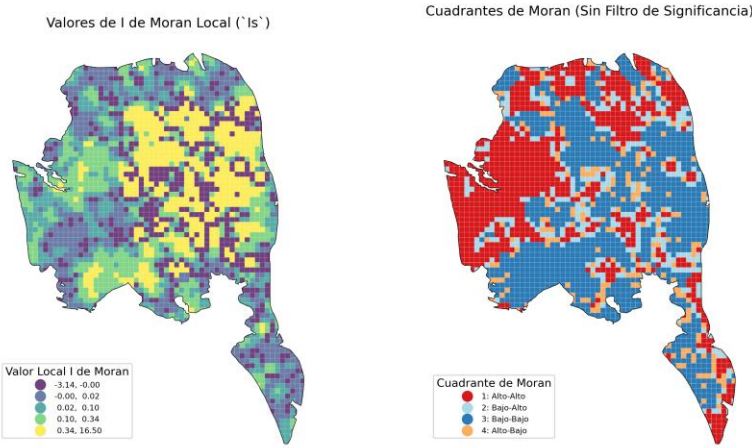


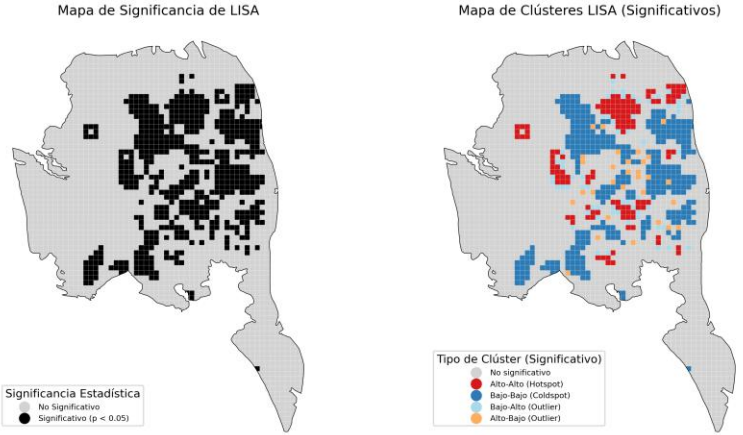
Autocorrelación espacial global

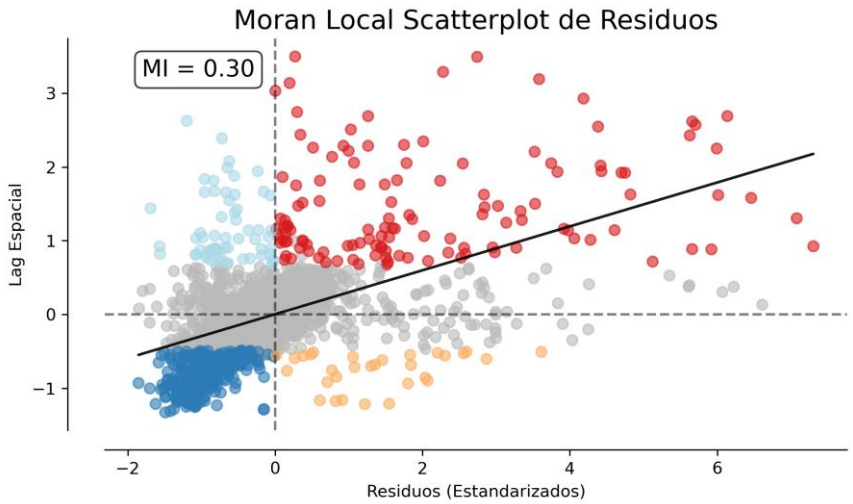




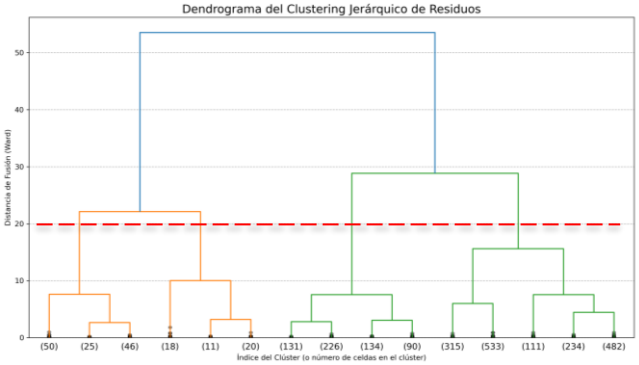
Autocorrelación espacial local

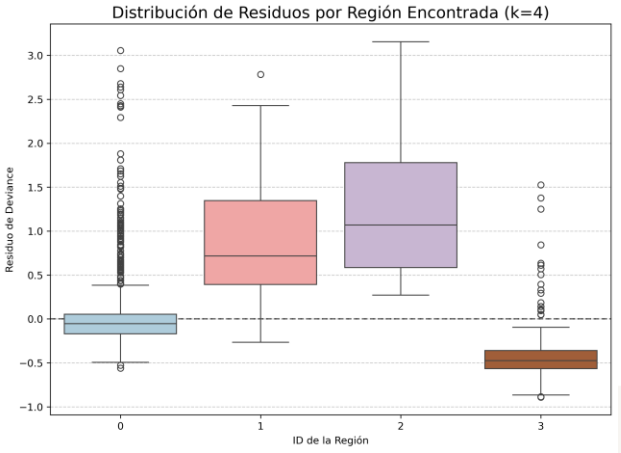


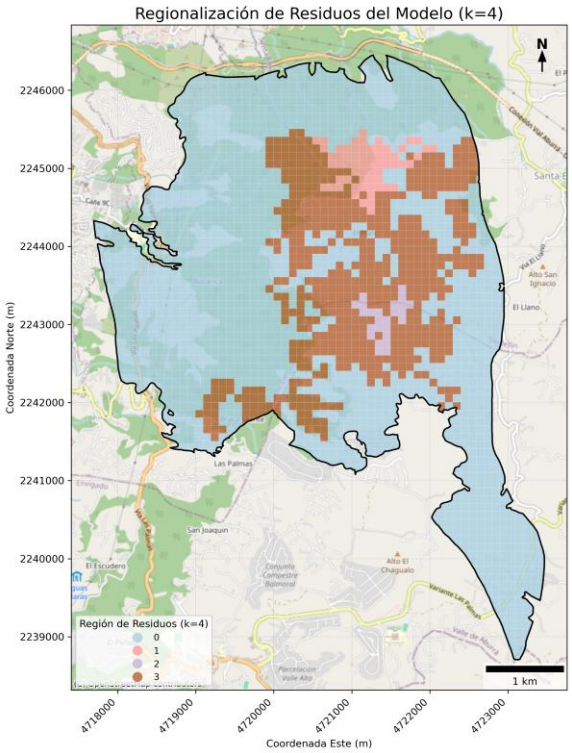




Agrupamiento espacial (Regionalización)







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                Number of Observations:        2426
Mean dependent var  :      1.4596                Number of Variables   :           9
S.D. dependent var  :      1.7774                Degrees of Freedom    :        2417
Pseudo R-squared    :      0.2938
Spatial Pseudo R-squared:  0.1093
Log likelihood      :  -4496.4363
Sigma-square ML     :      2.2615                Akaike info criterion :    9010.873
S.E of regression   :      1.5038                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 =====================================
```

Modelo de regresión para dependencia espacial tipo CAR

```
SUMMARY OF OUTPUT: GM SPATIALLY WEIGHTED LEAST SQUARES (HET)
-----------------------------------------------------------
Data set            :     unknown
Weights matrix      :       Queen
Dependent Variable  :       count                Number of Observations:        2426
Mean dependent var  :      1.4596                Number of Variables   :           8
S.D. dependent var  :      1.7774                Degrees of Freedom    :        2418
Pseudo R-squared    :      0.1011
N. of iterations    :           1                Step1c computed       :          No

------------------------------------------------------------------------------------
            Variable     Coefficient       Std.Error     z-Statistic     Probability
------------------------------------------------------------------------------------
            CONSTANT       -0.78526         0.56962        -1.37857         0.16803
            dem_mean        0.00041         0.00020         2.10545         0.03525
          slope_mean       -0.01783         0.00470        -3.79438         0.00015
            twi_mean        0.22467         0.06708         3.34924         0.00081
          dist_drain        0.00108         0.00063         1.71026         0.08722
          dist_fault        0.00072         0.00031         2.36494         0.01803
cov_Bosque fragmentado        0.20010         0.16255         1.23105         0.21831
cov_Mosaico de cultivos y espacios naturales         2.35329         1.87857         1.25270         0.21031
              lambda        0.59052         0.05666        10.42256         0.00000
------------------------------------------------------------------------------------
```

Modelo de regresión Ponderada Geográficamente (GWR)

Geographically Weighted Regression (GWR) Results

Spatial kernel:	Adaptive bisquare
Bandwidth used:	89.000

Diagnostic information

Residual sum of squares:	3926.495
Effective number of parameters (trace(S)):	344.788
Degree of freedom (n - trace(S)):	2081.212
Sigma estimate:	1.374
Log-likelihood:	-4026.409
AIC:	8744.393
AICc:	8859.740
BIC:	10747.888
R2:	0.487
Adjusted R2:	0.402
Adj. alpha (95%):	0.001
Adj. critical t value (95%):	3.252

Summary Statistics For GWR Parameter Estimates

Variable	Mean	STD	Min	Median	Max
X0	0.987	93.818	-1440.301	0.415	3885.712
X1	-0.968	7.134	-54.961	0.000	27.519
X2	-0.430	1.357	-11.640	-0.000	4.396
X3	0.153	0.551	-2.448	0.000	4.071
X4	0.034	0.421	-1.883	0.000	2.351
X5	0.110	0.772	-4.181	0.000	3.646
X6	-2.074	133.706	-3452.321	-0.160	4696.727
X7	5.578	1361.029	-32011.505	-5.618	33731.032

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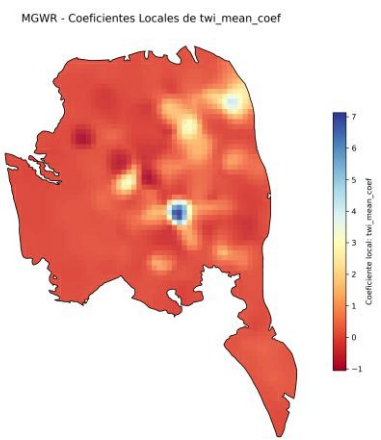
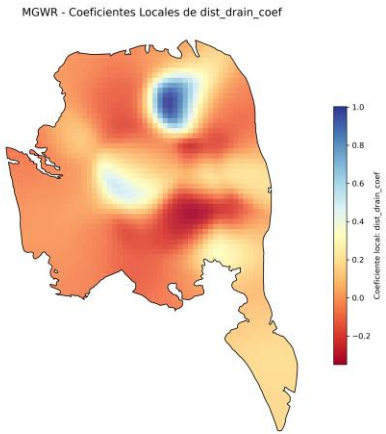
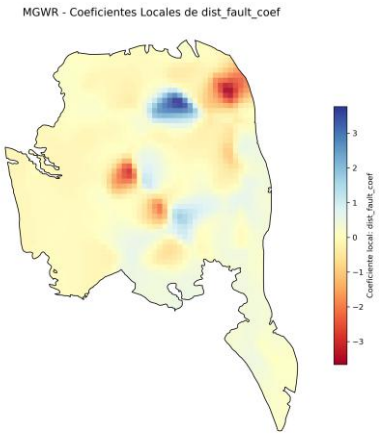
Regresión Ponderada Geográficamente Multiescala (MGWR)

```
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
===============================================================================
```







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Gracias

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