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## Apresentação de Artigo

# Determinants of Single Family residential water use across scales in four western US Cities

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**SER 301 – Análise Espacial de Dados Geográficos**

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# Introdução

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- Demanda crescente de água nos centros urbanos
  - Crescimento populacional;
  - Infraestrutura inadequada ou antiga;
  - Regulação ineficiente
  - Mudanças climáticas
- Necessidade: Conservação do recurso hídrico
- Compreensão: Demanda de água
  - Heterogeneidade espacial e temporal
  - Fatores determinantes
  - Padrões e tendências



# Introdução

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- Objetivo:
  - A. Quais são os padrões espaciais para demanda residencial de água (DRA)?
  - B. Quais são os fatores determinantes para DRA?
  - C. Como estes fatores variam em escala temporal e espacial?
  - D. Quais são os efeitos da vizinhança na DRA e como melhor é possível modelar este fenômeno?



# Métodos



## 1. Área de Estudo



4 municípios (EUA)  
Ano: 2011  
Escalas: CBG e CT

## 2. Variável Dependente



Demanda Residencial  
Mensal de Água (DRMA)  
Período: Anual, Verão e  
Inverno  
Agregação Espacial

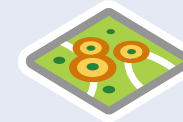
## 3. Variáveis Exploratórias



1. Temp. Máx. Mensal (°C)
2. Precipitação Mensal (mm)
3. Tamanho do Lote (ha)
4. Valor da propriedade (\$)
5. Idade do Imóvel (anos)
6. Superfície Impermeável (%)

Fontes: Dep. Municipais

## 4. Análise Exploratória Espacial



Índice Global de Moran (I)  
Getis e Ord (G)

## 5. Regressão Ordinária

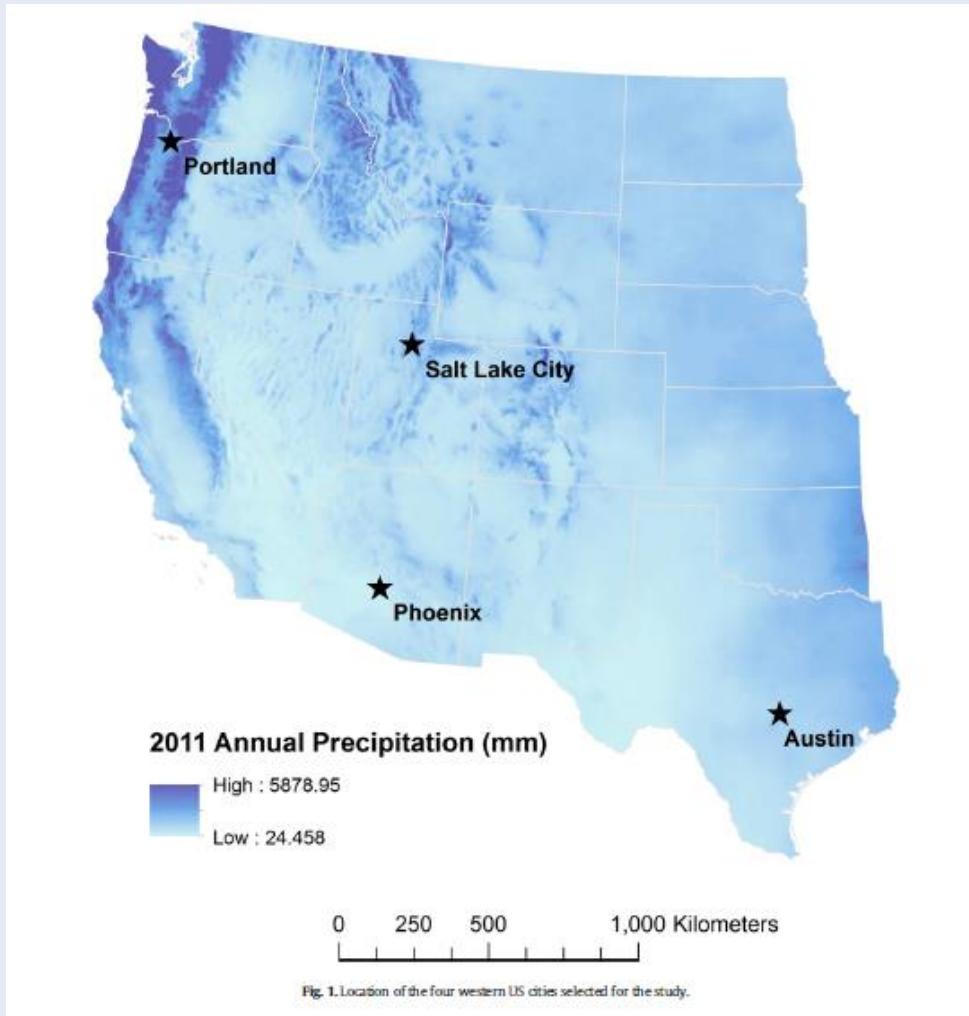


Método dos Mínimos  
Quadrados

## 6. Regressão Espacial



Spatial Lag Model (SAR)  
Spatial Error Model (CAR)  
Multiplicadores de Lagrange



- Portland (OR)
- Salt Lake City (UT)
- Phoenix (AZ)
- Austin (TX)
  
- Variabilidade
  - Climática
  - Populacional
  - Programas de Conservação do Recurso Hídrico

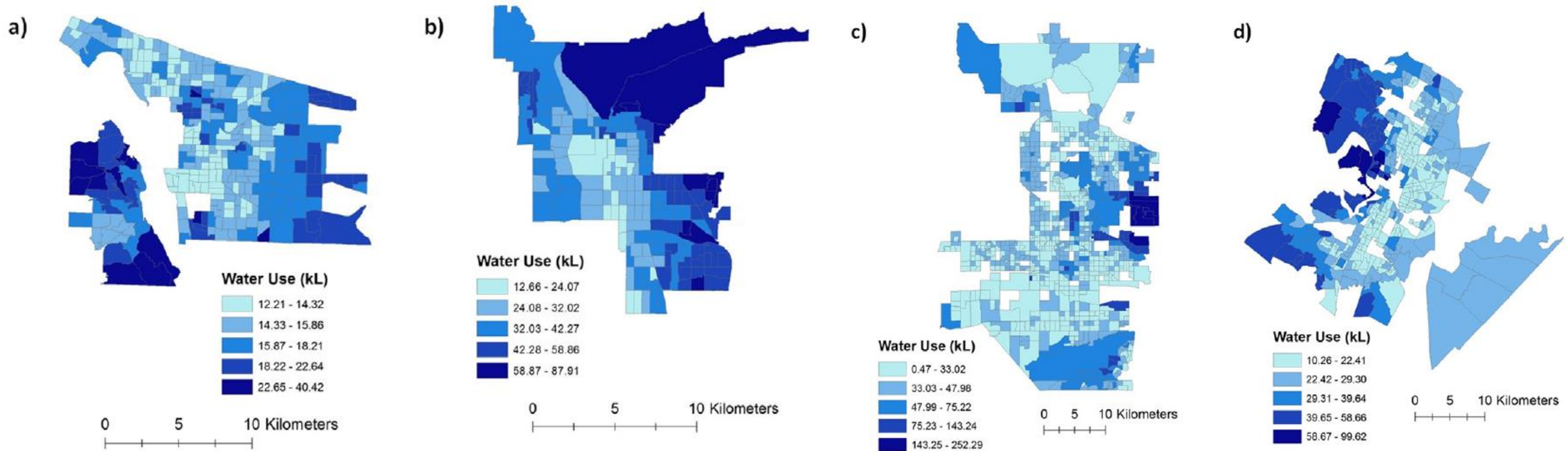


Fig. 2. Average monthly household water use at the Census Block Group level – a) Portland, Oregon; b) Salt Lake City, Utah; c) Phoenix, Arizona; and d) Austin, Texas. The missing block groups include primarily industrial or commercial, or park areas.

Variável Dependente - Demanda Residencial de Água (Média mensal)



**Table 3**

Mean and standard deviation values for the six chosen variables for explaining single family residential water use at the Census Block Group (CBG) and Census Tract (CT) scales for Austin, Phoenix, Portland, and Salt Lake City (numbers in parenthesis are standard deviation of each variable).

Data source: Salt Lake County.

City	Austin		Phoenix		Portland		Salt Lake City	
	CBG	CT	CBG	CT	CBG	CT	CBG	CT
Monthly maximum temperature, °C	28.24 (0.15)	28.23 (0.15)	29.70 (0.50)	29.72 (0.51)	15.70 (0.06)	15.70 (0.06)	16.51 (0.47)	16.51 (0.53)
Monthly precipitation, mm	36.96 (1.41)	36.94 (1.48)	10.49 (1.40)	10.46 (1.46)	90.98 (2.50)	91.26 (2.59)	49.26 (3.79)	49.24 (3.99)
Lot size, ha	0.01 (0.007)	0.02 (0.021)	0.22 (0.497)	0.26 (0.671)	0.01 (0.009)	0.08 (0.070)	0.07 (0.025)	0.07 (0.025)
Tax assessed value, \$10K	25.19 (17.33)	24.13 (14.98)	17.69 (25.66)	17.85 (20.43)	32.52 (14.53)	33.09 (12.70)	25.42 (10.33)	25.30 (12.95)
Building age, year	42.45 (22.91)	40.09 (21.55)	30.38 (20.06)	30.09 (19.74)	73.27 (17.92)	70.64 (16.93)	73.14 (22.40)	74.00 (21.61)
Impervious surface, %	40 (10.99)	40 (10.60)	10 (6.19)	10 (5.17)	48 (12.81)	47 (11.71)	55 (6.15)	55 (6.24)

## Variáveis Exploratórias

# Resultados



**Table 4**  
Comparison of Ordinary least squares (OLS) and spatial regression models for explaining average monthly single family residential water use at Census Block Group and Census Tract scales by city.

Variables	Austin		Phoenix		Portland		Salt Lake	
	OLS	Spatial	OLS	Spatial	OLS	Spatial	OLS	Spatial
Census Block Group	n = 375		n = 813		n = 335		n = 167	
Lot size (10 m <sup>2</sup> )	0.492	0.285						
Building age (year)	-0.160	-0.056	-0.078	0.087*	-0.046	-0.018	-0.228	-0.215
Assessed value (\$10K)	0.534	0.574	0.259	0.950	0.096	0.068	0.736	0.725
% Impervious			-0.656	-0.256	-0.066	-0.052	-0.351	-0.297
Lambda		0.75		0.82		0.69		0.54
AIC	2279.91	2114.97	7139.48	6481.61	1413.85	1324.97	1052.17	1025.01
R <sup>2</sup>	0.82	0.90	0.11	0.68	0.54	0.69	0.83	0.86
Residual's Moran's I	0.407	-0.070	0.618	-0.066	0.319	-0.039	0.265	-0.003
Census Tract	n = 138		n = 309		n = 105		n = 59	
Lot size (10 m <sup>2</sup> )	0.208	0.146						
Building age (year)	-0.211	-0.125	-0.116	-0.125*	-0.084	-0.053	-0.234	-0.228
Assessed value (\$10K)	0.527	0.546	0.459	0.240	0.136	0.092	0.725	0.714
% Impervious			-0.998	-0.817			-0.389	-0.338
Lambda		0.69		0.86		0.64		0.48
R <sup>2</sup>	0.86	0.91	0.22	0.69	0.65	0.75	0.91	0.93
Residual's Moran's I	0.309	-0.009	0.514	0.037	0.296	-0.049	0.227	-0.007

Idade do Imóvel (-)

Valor da propriedade (+)

Spatial Error Regression

Lambda: estatisticamente significativo nas 4 cidades

Only the coefficients of the statistically significant factors ( $p < 0.05$ ) are reported in the table, except marked as \* significant at the 0.1 level. AIC = Akaike information criterion; R<sup>2</sup> for spatial models are Pseudo-R<sup>2</sup> values.

## Comparação dos modelos – Média Mensal



# Resultados



**Table 5**  
Comparison of Ordinary least squares (OLS) and spatial regression models for explaining average winter (December–February) monthly single family residential water use at Census Block Group and Census Tract scales by city.

Variables	Austin		Phoenix		Portland		Salt Lake	
	OLS	Spatial	OLS	Spatial	OLS	Spatial	OLS	Spatial
Census Block Group	<i>n</i> = 375		<i>n</i> = 813		<i>n</i> = 335		<i>n</i> = 167	
Lot size (10 m <sup>2</sup> )	0.248	0.122						
Building age (year)	-0.075	-0.025	-0.068	NS	-0.010	NS	-0.082	-0.081
Assessed value (\$10K)	0.271	0.320	0.154	0.539				
% Impervious			-0.433	-0.230				
Tmax					9.815	9.700		
Lambda		0.76		0.80		0.89		0.55
AIC	1975.12	1766.61	6381.75	5803.8	649.15	257.08	829.23	797.19
R <sup>2</sup>	0.72	0.87	0.11	0.64	0.81	0.95	0.29	0.46
Residual's Moran's <i>I</i>	0.510	-0.089	0.580	-0.055	0.716	-0.074	0.304	-0.014
Census Tract	<i>n</i> = 138		<i>n</i> = 309		<i>n</i> = 105		<i>n</i> = 59	
Lot size (10 m <sup>2</sup> )	0.108	0.067						
Building age (year)	-0.101	-0.059	-0.094	-0.100	-0.049	-0.025	-0.094	-0.10
Assessed value (\$10K)	0.253	0.278	0.285	0.149	0.037	0.036		
% Impervious			-0.634	-0.515				
Lambda		0.74		0.84		0.74		0.50
AIC	679.65	615.03	2343.78	2162.62	291.50	242.84	276.50	267.33
R <sup>2</sup>	0.74	0.87	0.23	0.65	0.49	0.73	0.40	0.52
Residual's Moran's <i>I</i>	0.465	-0.023	0.475	0.035	0.471	-0.066	0.276	-0.013

Only the coefficients of the statistically significant factors ( $p < 0.05$ ) are reported in the table, NA = not significant, OLS = Ordinary least squares; AIC = Akaike information criterion; R<sup>2</sup> for spatial models are Pseudo-R<sup>2</sup> values.

Idade do Imóvel (-)

Spatial Error Regression

Lambda: estatisticamente significativo nas 4 cidades

## Comparação dos modelos – Inverno

# Resultados



**Table 6**  
Comparison of Ordinary least squares (OLS) and spatial regression models for explaining average summer (June–September) monthly single family residential water use at Census Block Group and Census Tract scales by city.

Variables	Austin		Phoenix		Portland		Salt Lake	
	OLS	Spatial	OLS	Spatial	OLS	Spatial	OLS	Spatial
Census Block Group	n = 375		n = 813		n = 335		n = 167	
Lot size (10 m <sup>2</sup> )	0.704	0.448						
Building age (year)	-0.258	-0.104			-0.061	-0.338	-0.509	-0.473
Assessed value (\$10K)	0.802	0.849	0.348	0.130	0.175	0.128	2.031	1.917
% Impervious	-0.170	-0.142	-0.920	-0.377	-0.120	-0.108	-0.863	-0.718
Tmax								
Lambda		0.74		0.82		0.64		0.58
AIC	2589.04	2440.73	7670.73	7003.9	1789.62	1711.71	1332.48	1301.98
R <sup>2</sup>	0.83	0.90	0.11	0.68	0.53	0.67	0.86	0.89
Residual's Moran's I	0.376	-0.051	0.633	-0.073	0.307	-0.014	0.273	-0.009
Census Tract	n = 138		n = 309		n = 105		n = 59	
Lot size (10 m <sup>2</sup> )	0.288	0.227						
Building age (year)	-0.354	-0.248			-0.086	-0.047	-0.509	-0.465
Assessed value (\$10K)	0.780	0.802	0.604	0.323	0.195	0.123	0.213	1.916
% Impervious	-0.289	-0.257	-1.415	-1.093	-0.097	-0.124	-0.886	-0.778
Tmax								
Lambda		0.61		0.87		0.62		0.62
AIC	871.37	847.09	2852.85	2629.11	521.89	494.40	424.89	412.75
R <sup>2</sup>	0.89	0.92	0.21	0.70	0.63	0.75	0.93	0.95
Residual's Moran's I	0.246	0.002	0.533	0.042	0.333	-0.023	0.275	-0.001

Only the coefficients of the statistically significant factors ( $p < 0.05$ ) are reported in the table. OLS = Ordinary least squares; AIC = Akaike information criterion; R<sup>2</sup> for spatial models are Pseudo-R<sup>2</sup> values.

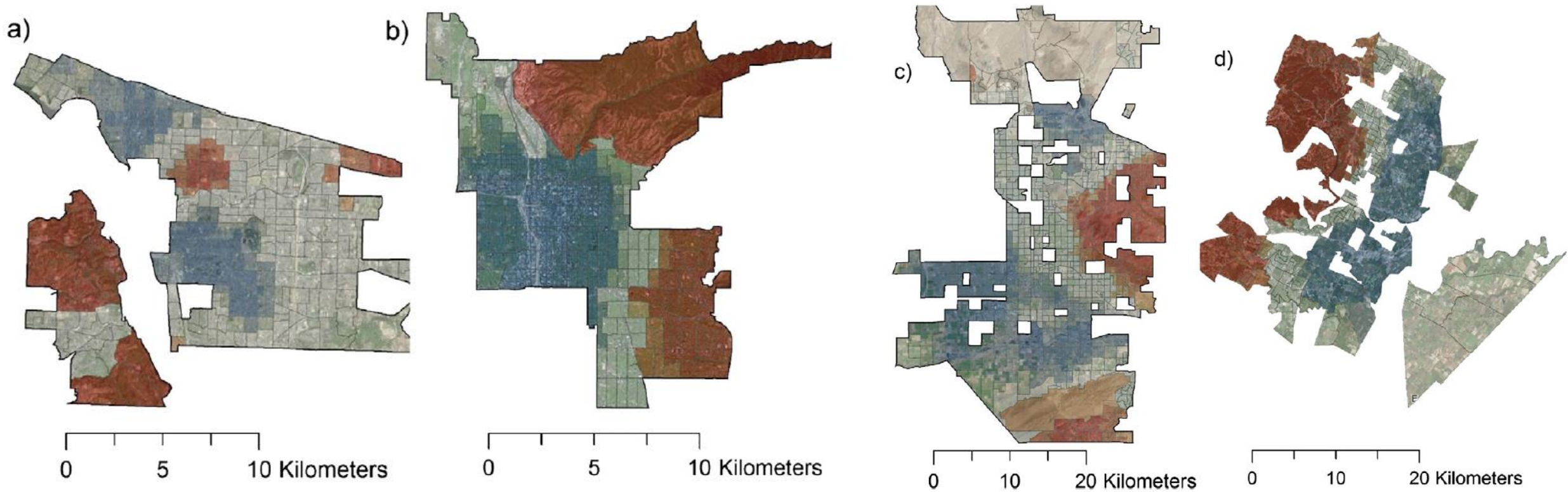
Valor da propriedade (+)

Superfície Impermeável (-)

Spatial Error Regression

Lambda: estatisticamente significativo nas 4 cidades

## Comparação dos modelos – Verão



**Fig. 5.** Hotspots (red) and cold spots (blue) of summer (June–September) household water use at the census block group scale based on the Getis-Ord  $G_i^*$  statistic - a) Portland, Oregon; b) Salt Lake City, Utah; c) Phoenix, Arizona; and d) Austin, Texas.

## Hotspots e Cold Spots – Getis-Ord $G_i^*$ (Verão)

# Discussão

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- Spatial Error Model (CAR)
  - $R^2$  mais elevados de comparado ao MMQ
  - Inclusão da variável espacial: melhora em todos os cenários
- Variação sazonal
- Variação da escala:
  - CT: maior capacidade preditiva
  - MAUP
- Indicativo:
  - Novas residências: maior demanda de água



# Conclusão

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- Fortes evidências de gradiente espacial na DRA entre as cidades
  - Regiões mais novas com maiores DRA
- Principais fatores determinantes: Valor da propriedade e idade do imóvel
- Variabilidade nos resultados entre as escalas
- Melhores resultados: Spatial Error Regression (CAR)
  - Forte dependência espacial e efeitos da vizinhança



# Referência Bibliográfica

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- Chang, H., Bonnette, M. R., Stoker, P., Crow-Miller, B., Wentz, E., 2017. Determinants of single family residential water use across scales in four western US cities. Science of The Total Environment; 596-597: 451  
DOI: 10.1016/j.scitotenv.2017.03.164





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# Obrigado!

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