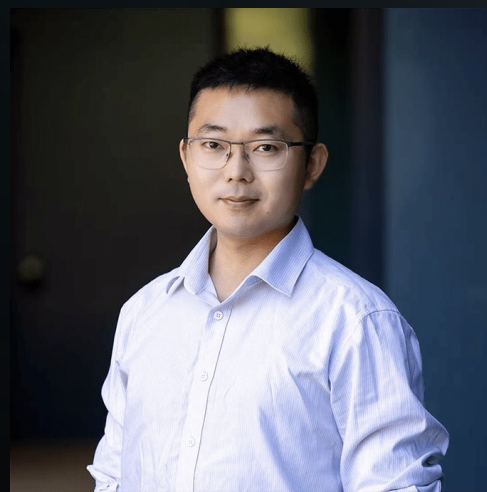


Geospatial Data Analysis, Prediction, and GeoAI: New Theories, Methods, and Software

Topic 4. Spatial patterns for prediction

Lecture website: <https://yongzesong.com/lecture-20260104>



Yongze Song, Associate Professor

School of Design and the Built Environment, Curtin University, Australia
RGS Fellow (UK), DAAD Alnet Fellow (Germany), SDL Fellow (Harvard University, US)

Email: Yongze.song@curtin.edu.au

Associate Editor: *International Journal of Earth Observation and Geoinformation* (IF 8.6, Q1)

Associate Editor: *GIScience & Remote Sensing* (IF 6.9, Q1)

Topic Editor: *Geoscientific Model Development* (IF 4.9, Q1)

Lecture outline

Lecture website: <https://yongzesong.com/lecture-20260104>

Password: 20260104

Contents

Part 1. Lecture (1st class)

1. Concepts of spatial patterns
2. Geocomplexity
3. Local outliers (SDO)

Part 2. Practice (2nd to 4th classes)

1. Feedback session for Assignment 3 (20 min)
2. Practice on geocomplexity (40 min)
3. Assignment 4 (40 min)
4. Submit your assignment (10 min)

Tips:

1. Working in a group of 3 or 4
2. Collecting feedback at each day
3. Individual assignments and working in a group
4. Complete assignments in the class
5. Assignment feedback sections after day 2
6. Install R and Rstudio
7. Sign Up for Google Earth Engine

Concepts of spatial patterns

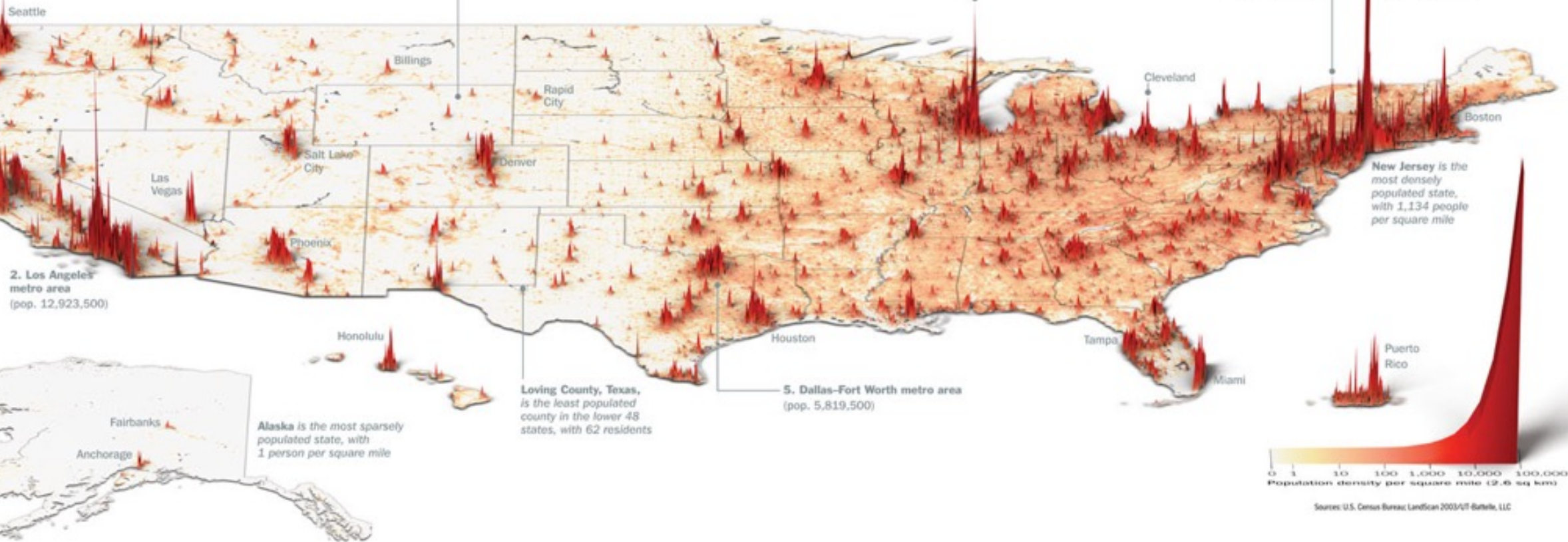
80% of the U.S. population lives in a metropolitan area
Populations of top five shown

The entire state of Wyoming (pop. 509,300) has fewer people than the Harrisburg, Pa., metro area

3. Chicago metro area (pop. 9,443,400)

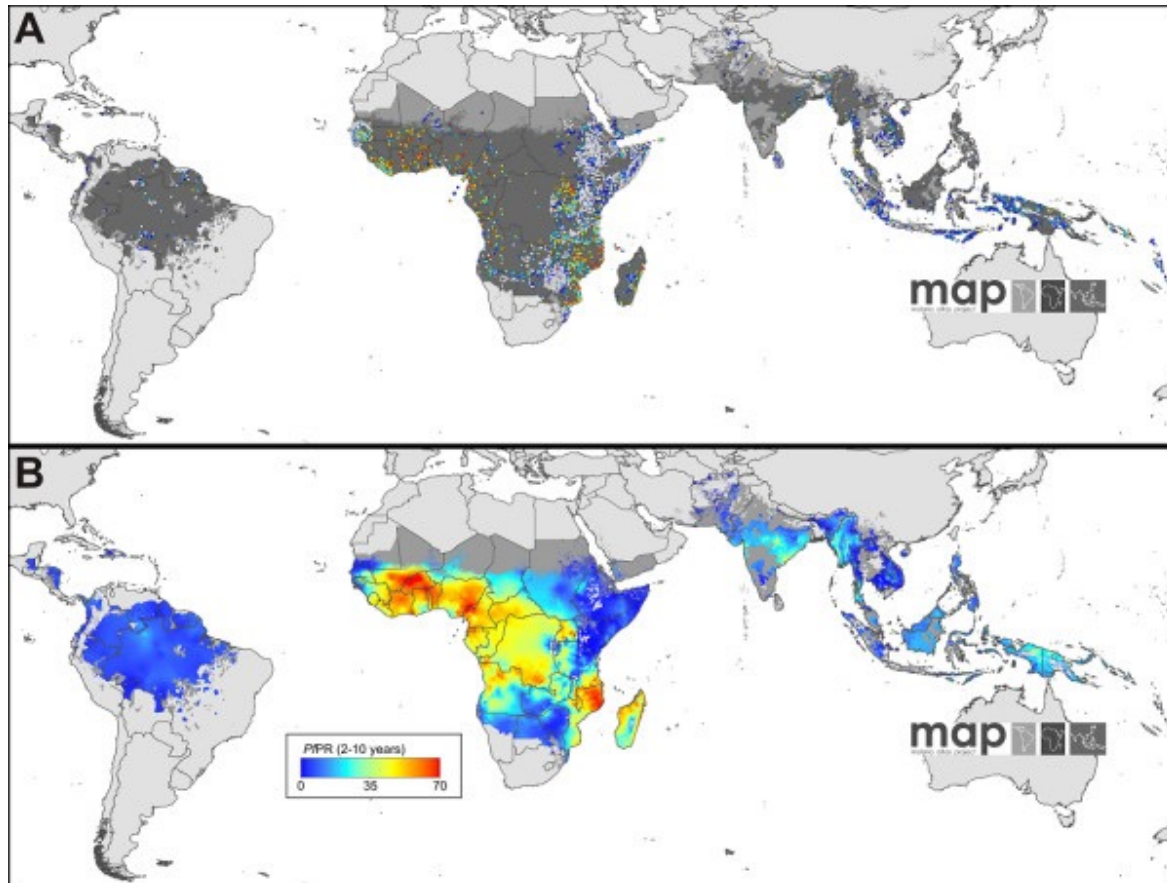
4. Philadelphia metro area (pop. 5,823,200)

1. New York City metro area (pop. 18,747,300)

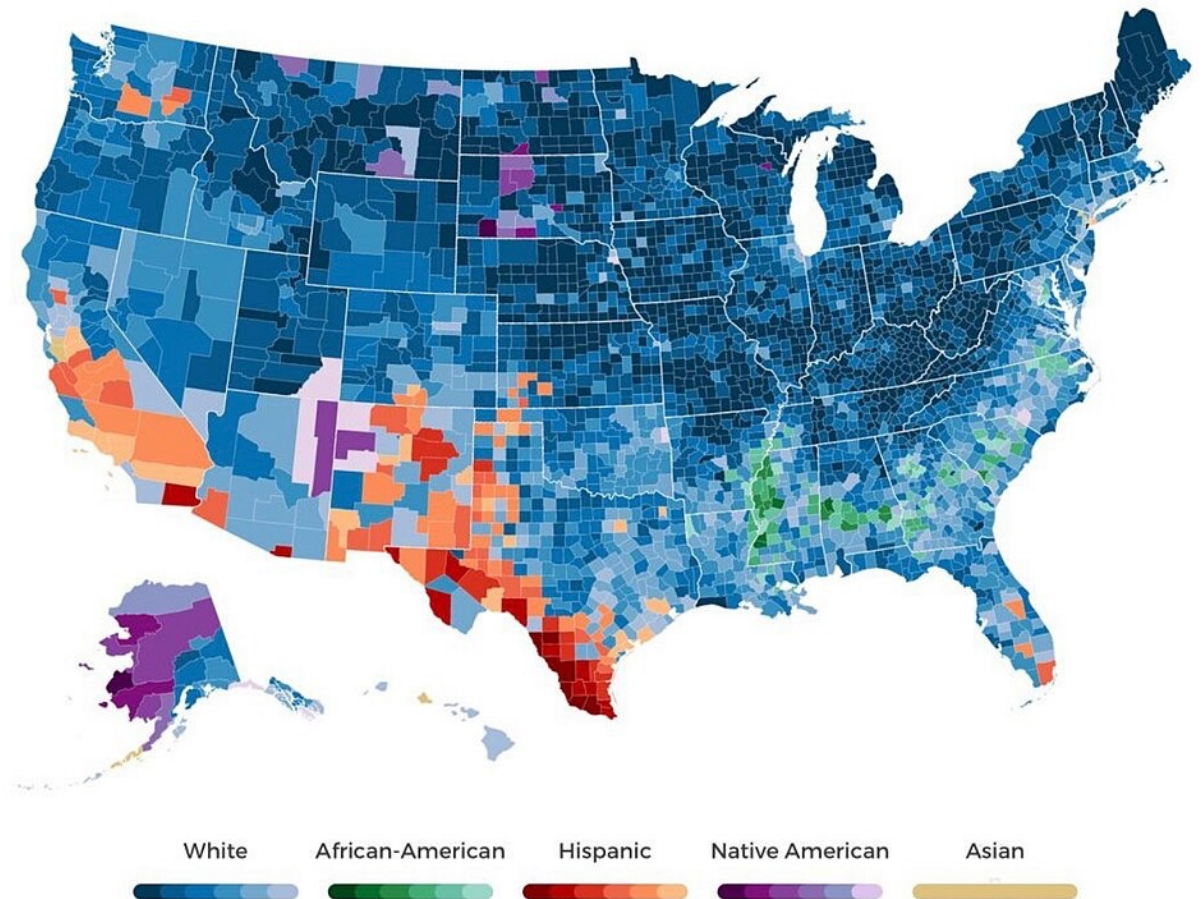


Concepts of spatial patterns

World malaria map



Largest Race and Ethnicity in United States



*Malaria Atlas Project, [Demographics of the United States](#)

Concepts of spatial patterns

Spatial patterns describe a variable's distribution across space and the similarity or dissimilarity among nearby locations, including gradients, clusters, and hotspots.

They capture both spatial heterogeneity and spatial dependence by revealing where values are concentrated, dispersed, or structured at different scales.

Geocomplexity provides an effective way to quantify the local complexity of spatial data by summarising neighborhood-based irregularity and spatial association into interpretable, location-specific patterns.

Geocomplexity explains spatial errors

Geocomplexity: Geographically local complexity

GeoComplexity = Local feature + Surrounding feature

$$\begin{aligned}
 \text{Spatial pattern complexity at location } i &= -\frac{1}{m} Z_i \sum_{j=1}^m W_{ij} \cdot Z_j - \frac{1}{m} \sum_{j=1}^m W_{ij} \cdot Z_j \frac{1}{p_k} \sum_{k=1}^n W_{kj} \cdot W_{ki} \cdot Z_k \\
 &= -\frac{1}{m} \sum_{j=1}^m [Z_i \cdot Z_j + \frac{1}{p_k} \sum_{k=1}^n Z_j \cdot Z_k]
 \end{aligned}$$

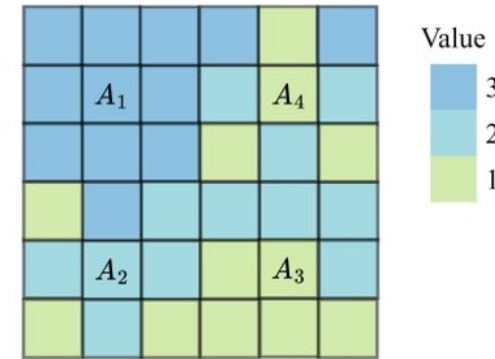
LISA

j_1	j_2	j_3
j_4	i	j_5
j_6	j_7	j_8

All the neighbours of the location i are considered in GeoComplexity

k_1	j	k_2
k_3	i	k_4

Under the queen criterion, when j is one of the neighbours of the location i , $\{k_i\}$ are neighbours of both j and i .



Spatial pattern complexity at

$A_1 : -2.90$ simple

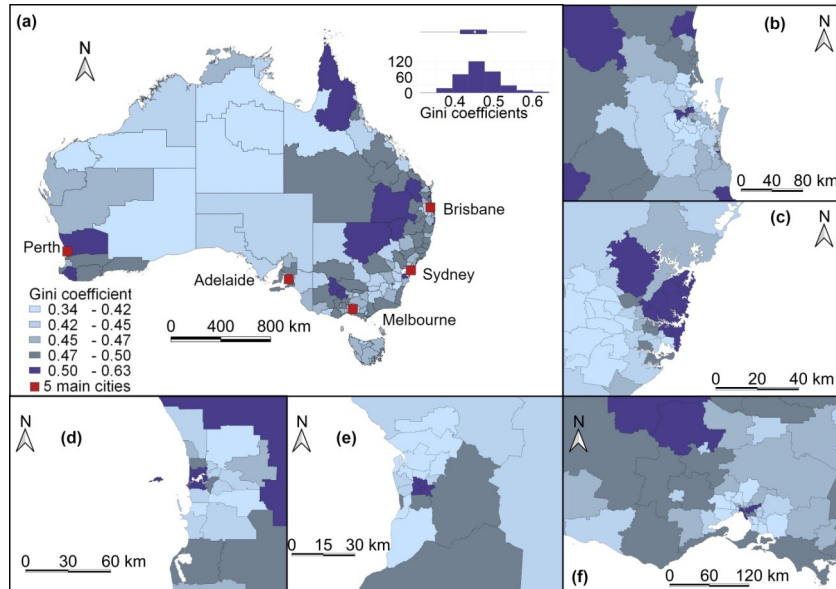
$A_2 : 0.13$ complex

$A_3 : -1.22$ medium

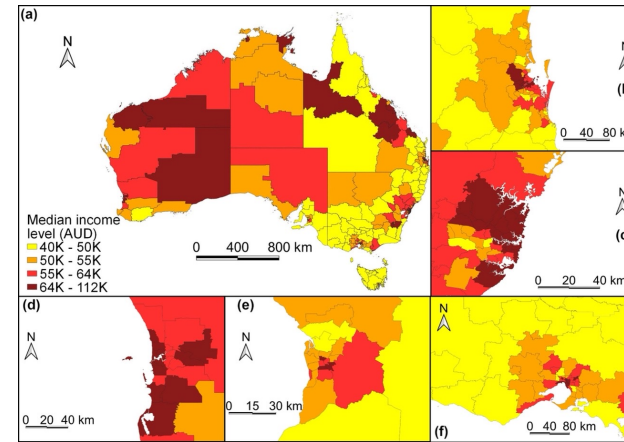
$A_4 : 0.09$ complex

Geocomplexity explains spatial errors

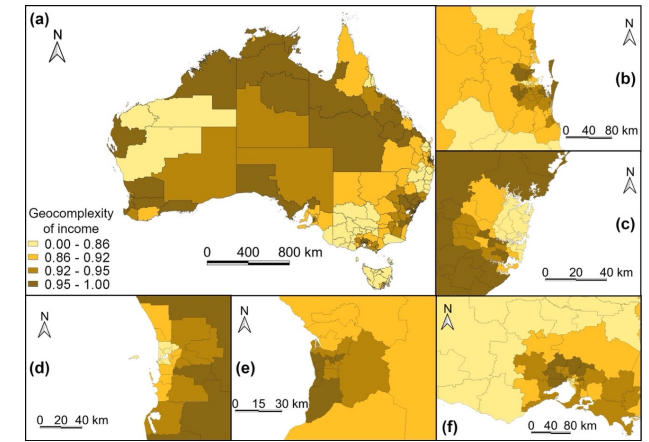
Regional Gini coefficients



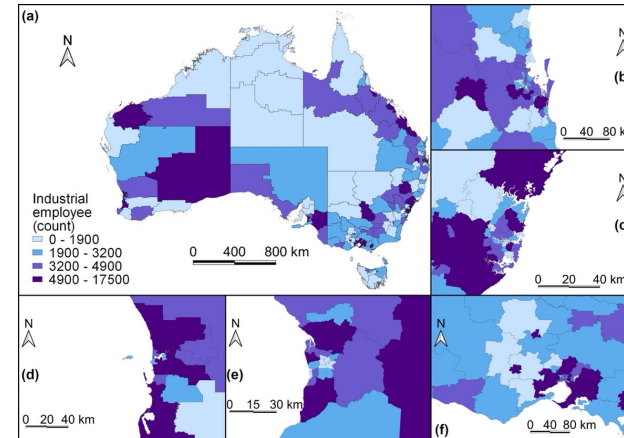
Income



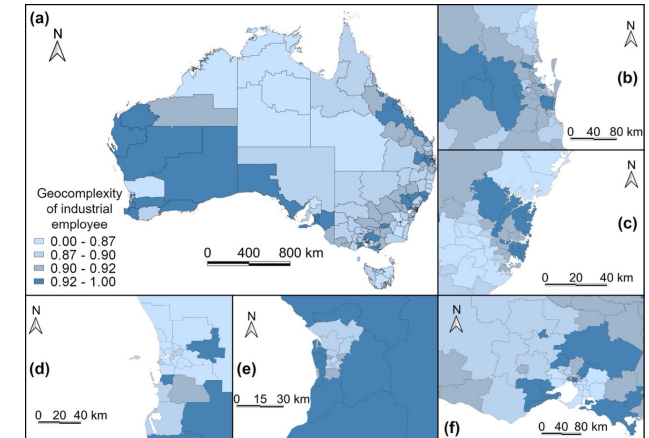
Geocomplexity of income



Industrial employees



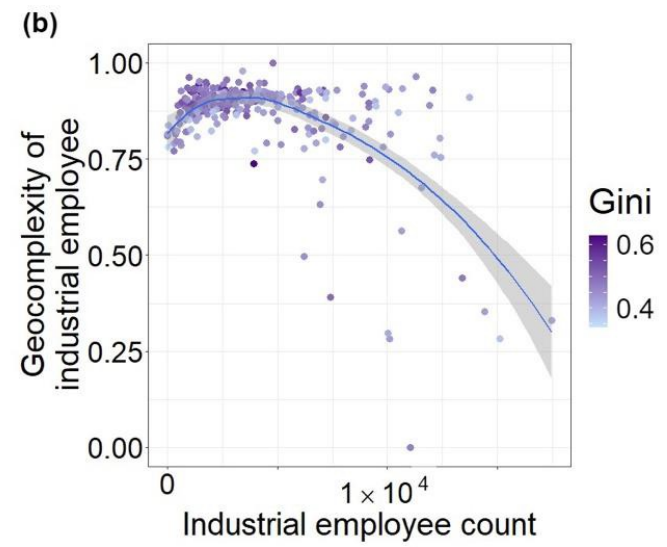
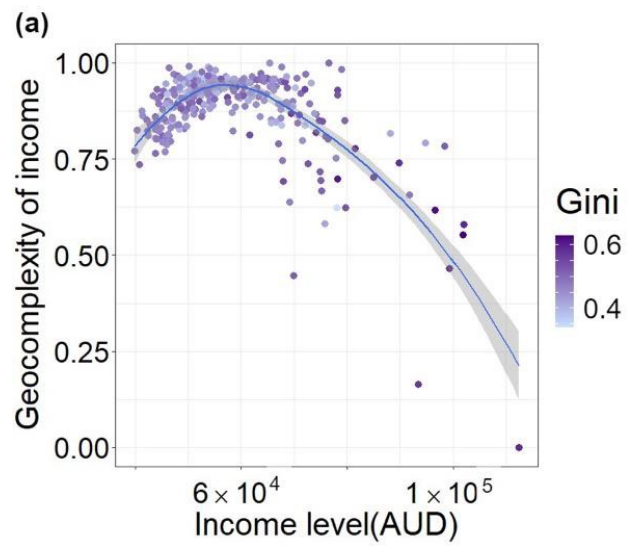
Geocomplexity of industrial employees



Zhang, Z., Song, Y.*, Luo, P., & Wu, P. Geocomplexity explains spatial errors. *International Journal of Geographical Information Science*. 2023

Geocomplexity explains spatial errors

Relationships between spatial data and their geocomplexity



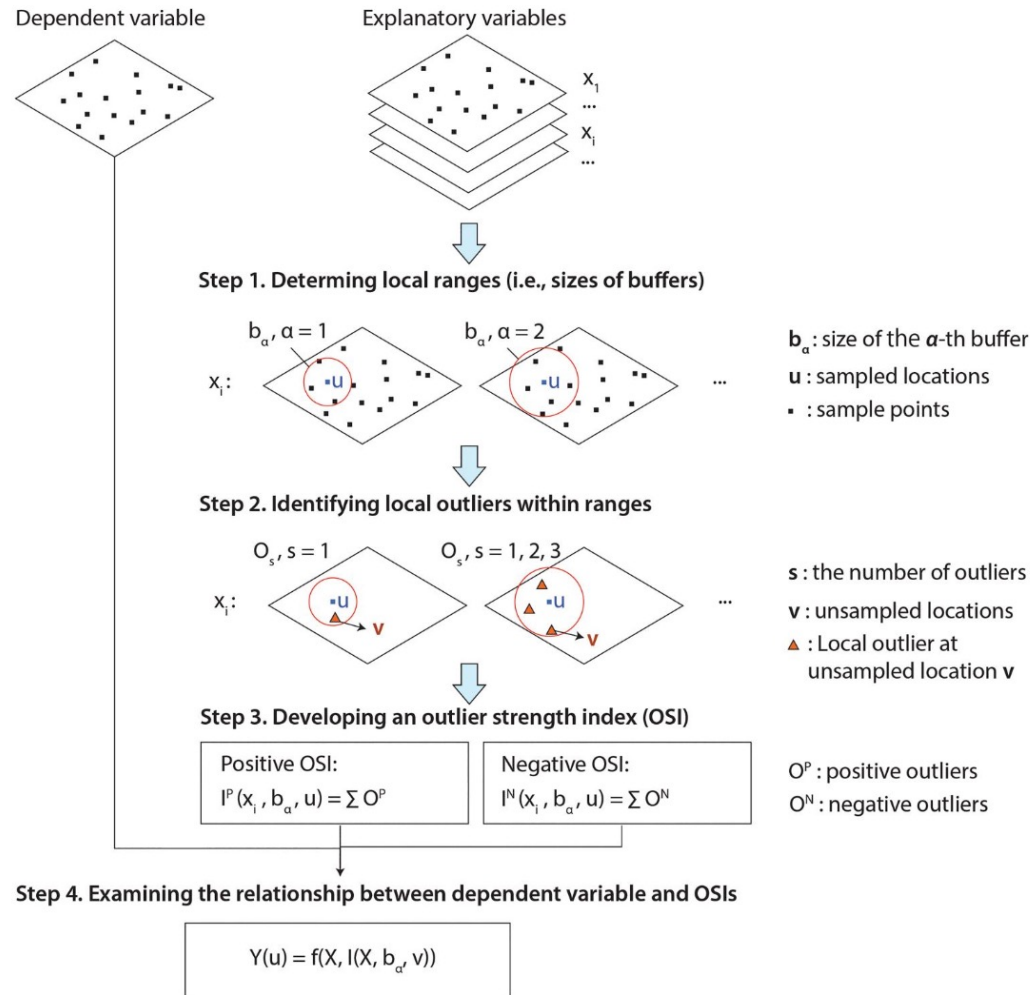
The power of geocomplexity in explaining spatial errors

Geocomplexity explains:

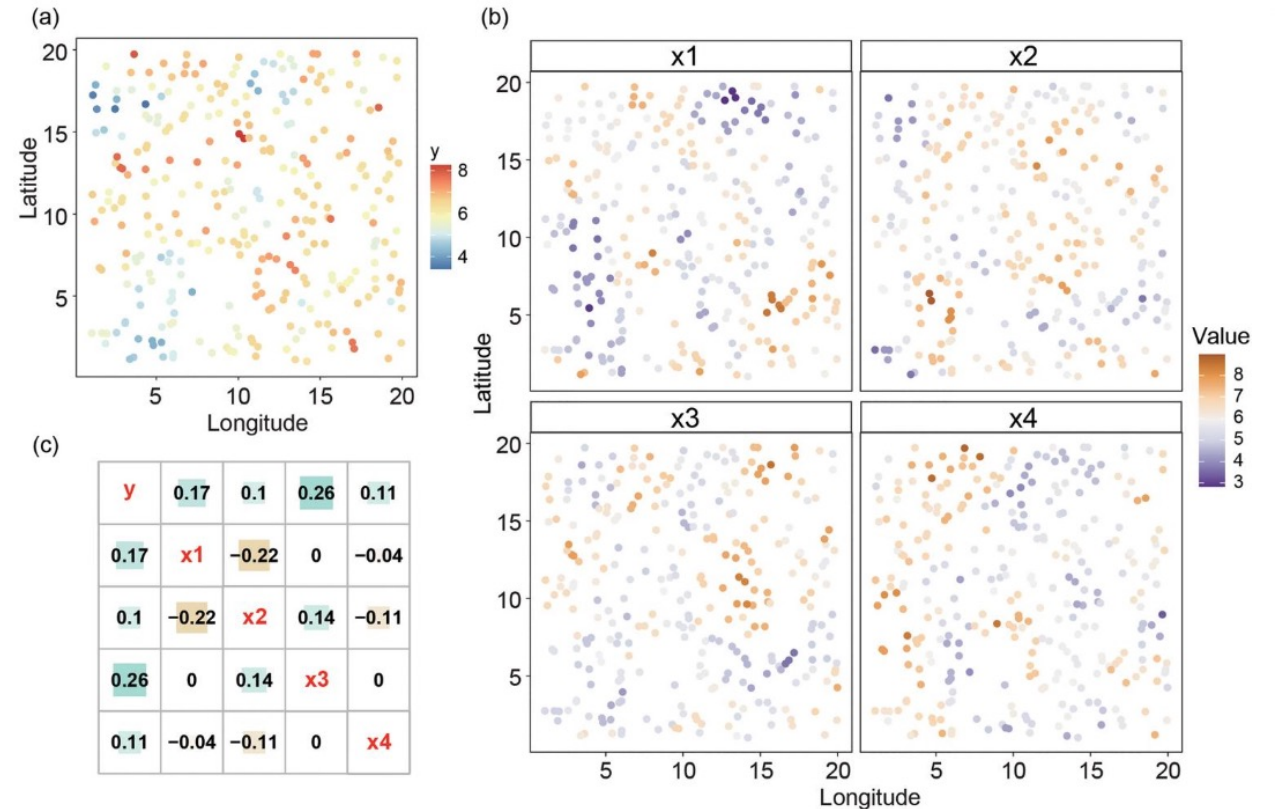
- 47% of multivariate regression errors
- 17% of support vector regression errors
- 14% of geographically weighted regression errors

Zhang, Z., Song, Y.*, Luo, P., & Wu, P. Geocomplexity explains spatial errors. International Journal of Geographical Information Science. 2023

Second-dimension outliers for prediction



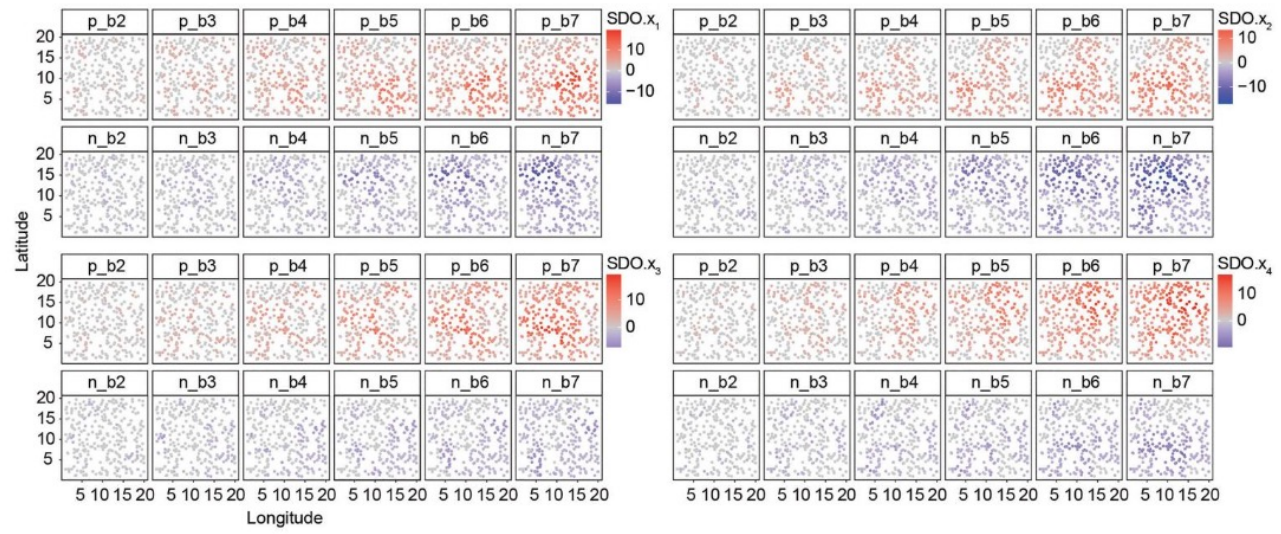
Simulation data



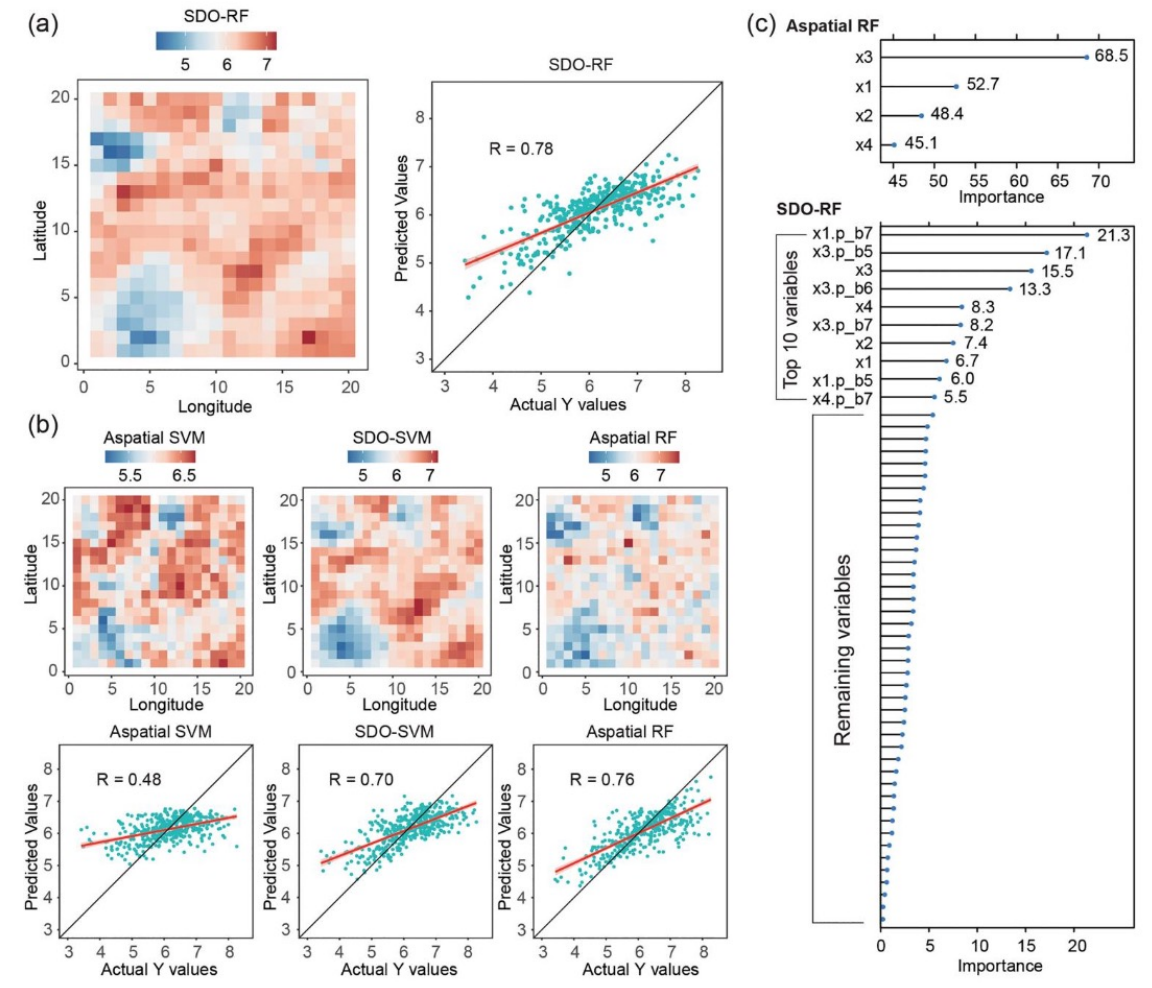
Ren, K., Song, Y.* and Yu, Q., 2025. Second-dimension outliers for spatial prediction. International Journal of Geographical Information Science.

Second-dimension outliers for prediction

Second-dimension outliers

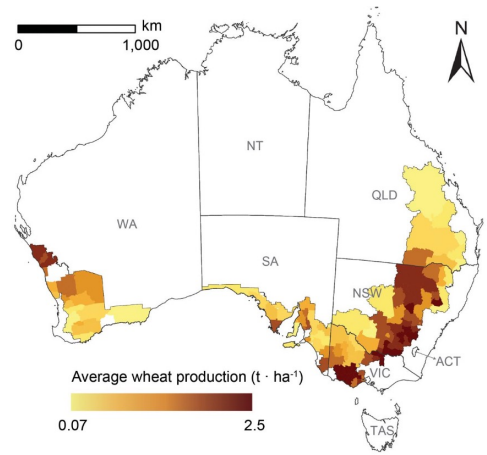


SDO model vs Random forest (RF)

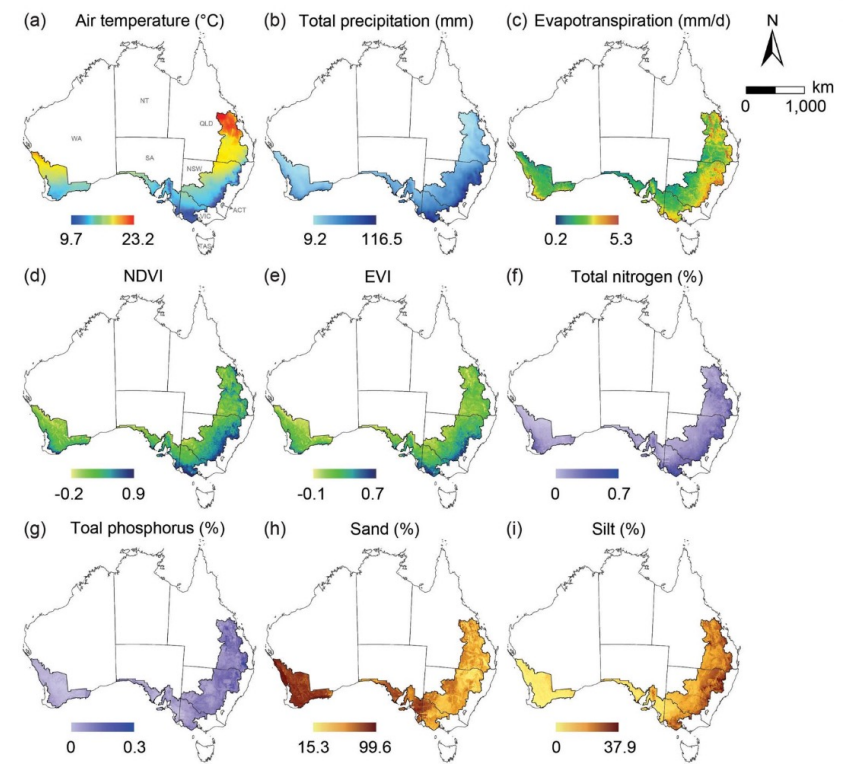


Ren, K., Song, Y.* and Yu, Q., 2025. Second-dimension outliers for spatial prediction. International Journal of Geographical Information Science.

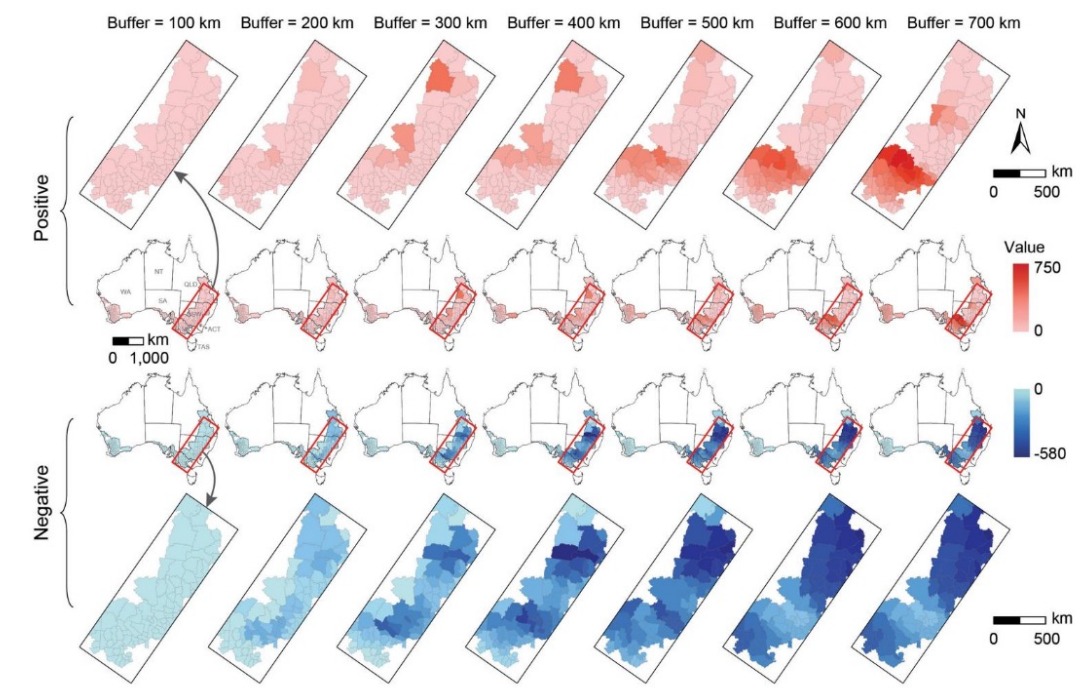
Second-dimension outliers for prediction



Wheat production



Climate and environment



SDO variables

Ren, K., Song, Y.* and Yu, Q., 2025. Second-dimension outliers for spatial prediction. International Journal of Geographical Information Science.

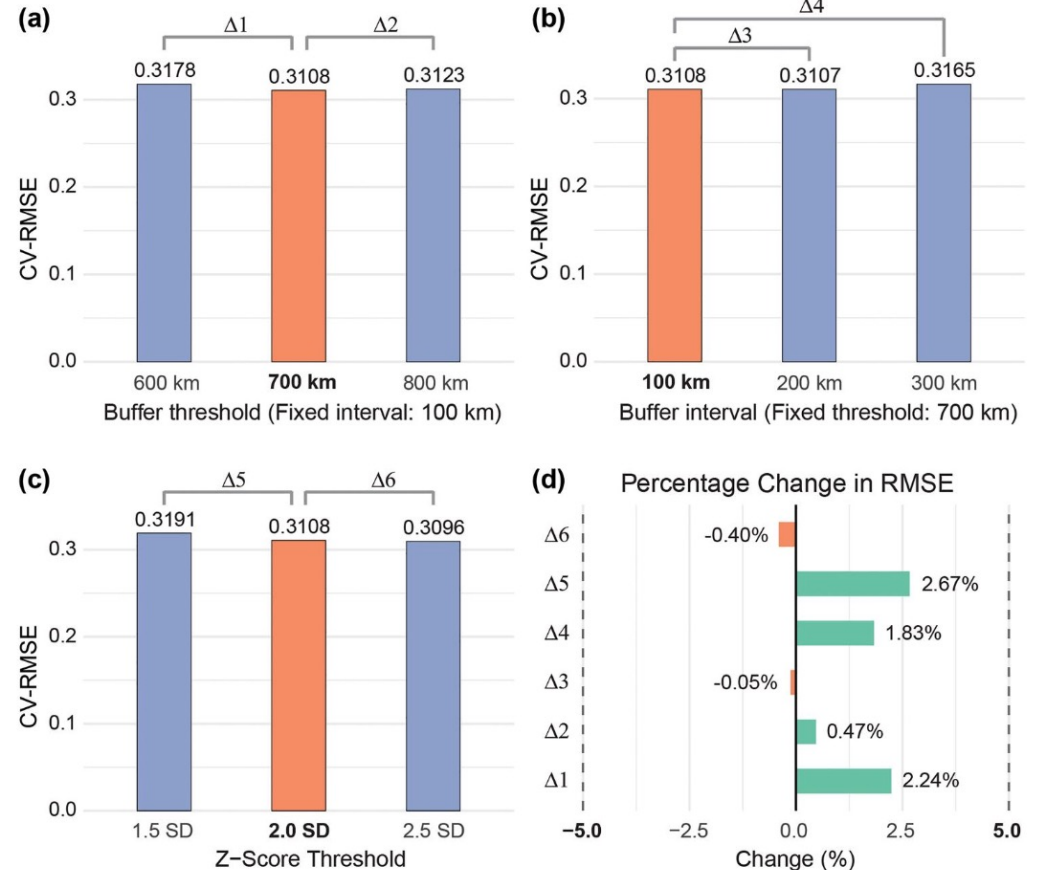
Second-dimension outliers for prediction

Accuracy

Table 2. Improvements of model accuracy in machine learning by SDO models compared with aspatial models (bold values indicating the best-performing SDO results).

Model		RF	CRM	XGB	SVM	GBM	KNN	ENR
R^2	Aspatial	0.527	0.634	0.548	0.555	0.496	0.455	0.580
	SDO	0.615	0.590	0.628	0.671	0.596	0.637	0.585
	Improvement	16.7%	-6.9%	14.6%	20.9%	20.2%	40.0%	0.9%
RMSE	Aspatial	0.368	0.321	0.370	0.355	0.377	0.400	0.343
	SDO	0.338	0.350	0.330	0.311	0.337	0.321	0.360
	Reduction	8.2%	-9.0%	10.8%	12.4%	10.6%	19.8%	-5.0%
MAE	Aspatial	0.279	0.241	0.286	0.267	0.283	0.310	0.272
	SDO	0.256	0.254	0.243	0.231	0.248	0.241	0.265
	Reduction	8.2%	-5.4%	15.0%	13.5%	12.4%	22.3%	2.6%

Sensitivity



Ren, K., Song, Y.* and Yu, Q., 2025. Second-dimension outliers for spatial prediction. International Journal of Geographical Information Science.

Geocomplexity for measuring spatial patterns

Practice

R Code in website

Assignment 4

You will have 40 min for working on Assignment 4

Write a 200 word essay on the analysis of spatial patterns using geocomplexity.

Send to Email before 10 am next day:

Yongze.song@outlook.com

Document name: A4_YourName.docx

Any questions?