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Environment and Variation in Historic Settlement Patterns in England

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Using GIS for Determining Archaeological Locations
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Background to the Research Problem

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- Rural settlement organisation in England from the early medieval period onwards
- Basic contrast between ‘dispersed’ and ‘nucleated’ settlement
- Why are villages more common in some parts of England than others?
- ‘Cultural’ vs ‘environmental’ explanations – focus here is on environmental factors

Roberts and Wrathmell's *Atlas*

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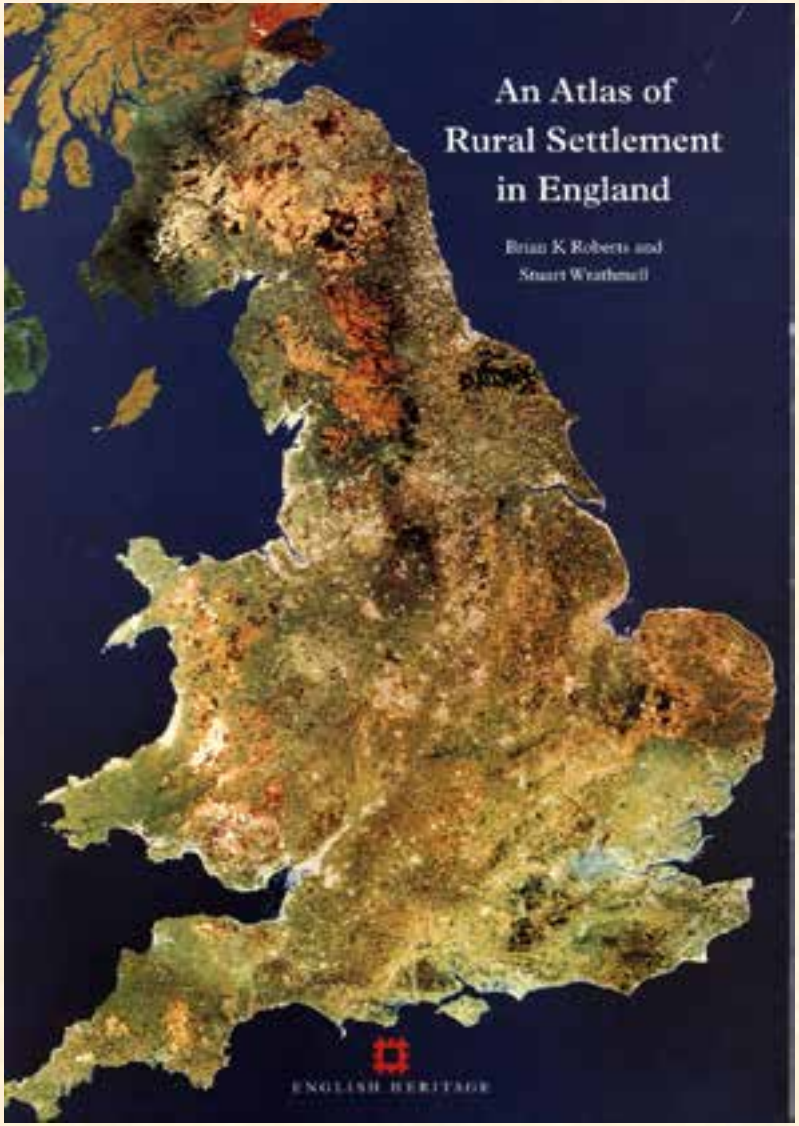

Brian Roberts and Stuart Wrathmell's *An Atlas of Rural Settlement in England* (London: 2000, revised 2003)

Roberts and Wrathmell's Provinces, Sub-Provinces and Local Regions

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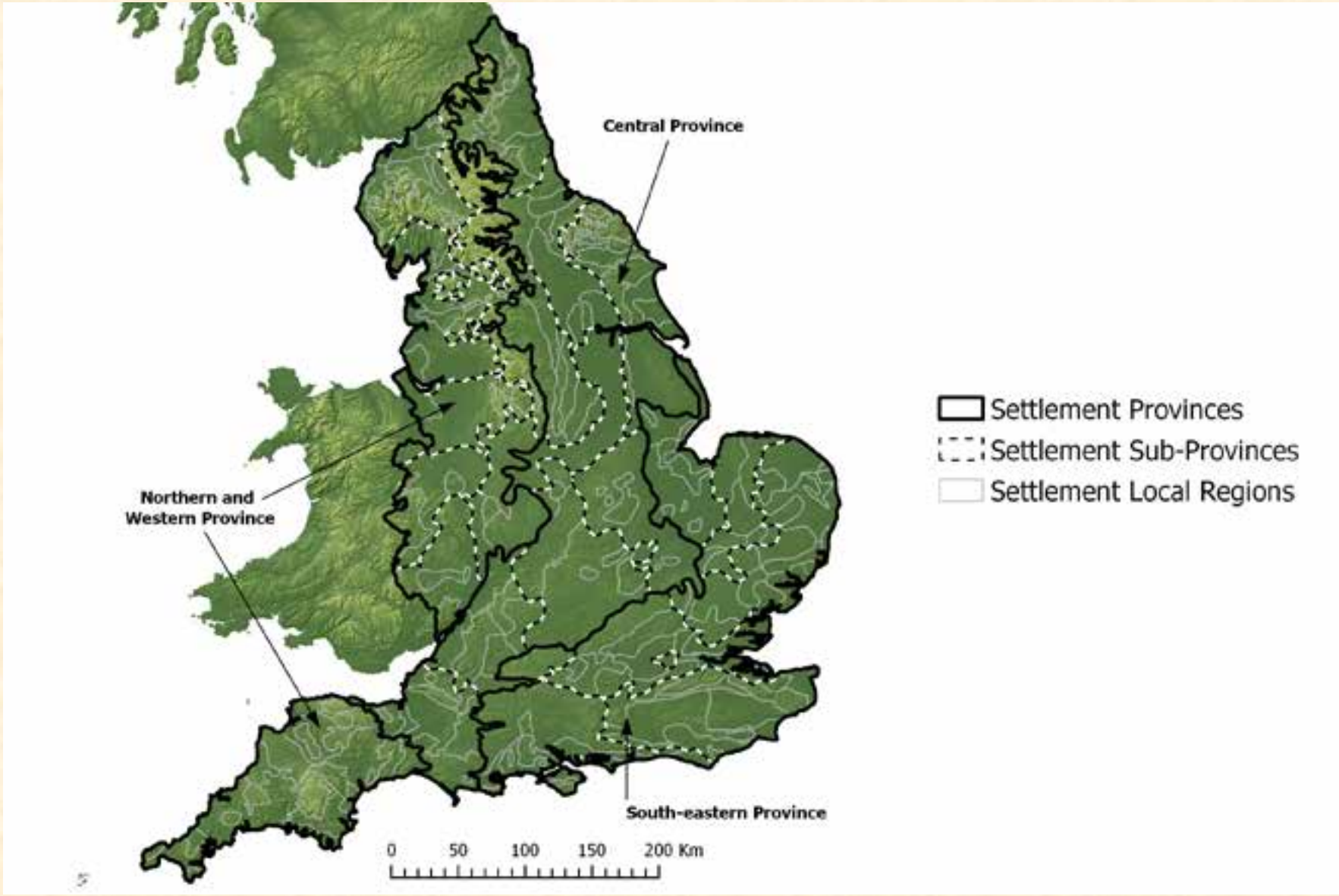

Analytical Approach

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1. Identify areas having similar forms of settlement organisation

2. Identify areas having similar sets of various relevant environmental factors (soils, precipitation, temperature, elevation)

3. Compare the spatial patterns found in #1 and #2 and evaluate how well they match

If the patterns match closely, one can make the interpretative leap that environmental factors strongly influenced patterns of settlement organisation

Roberts and Wrathmell's *Atlas* as GIS data

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- A. G. Lowerre, E. Lyons, B. K. Roberts and S. Wrathmell, *The Atlas of Rural Settlement in England GIS: Data, Metadata and Documentation* [Computer file] (English Heritage, 2011)

- Data (in Esri shapefile and KMZ formats), UK GEMINI 2.1-compliant metadata and detailed documentation are available for free

- Downloadable from:

http://www.english-heritage.org.uk/professional/research/archaeology/atlas-of-rural-settlement-gis/

Clusters of A) Similar Environmental Factors and B) Similar Forms of Settlement Organisation

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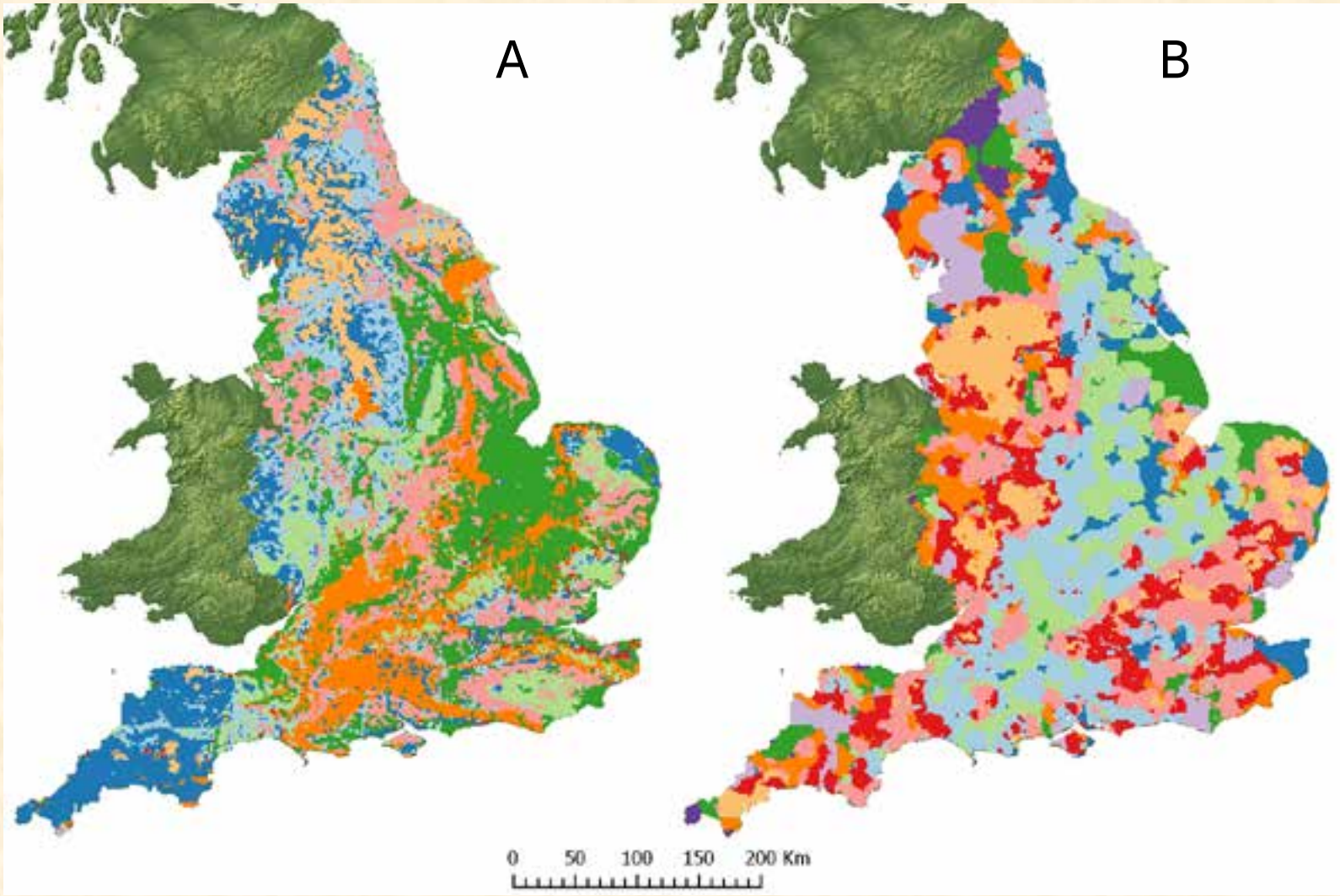

Clustering performed using Iso Cluster Unsupervised Classification

K = 8 for environmental factors; K= 10 for settlement data

A Test of Association Between Spatial Patterns in Polygon Data

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- Susan L. Maruca and Geoffrey M. Jacquez (2002) “Area-based tests for association between spatial patterns” *Journal of Geographical Systems* 4(1), 69-83

- Test aims to quantify how well two sets of polygons match
- Relative Area Overlap (RAO): based on the amount of overlap between polygons in each of two partitions
- Tests significance of the amount of overlap using a Monte Carlo randomisation procedure

- Maruca & Jacquez’s method provides a global RAO statistic; my enhancement provides a local RAO statistic: one for each polygon

Calculating Relative Area Overlap

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- Two sets of polygons: I and J
- For each pair of overlapping polygons in I and J, calculate the ratio of the area of intersection to the area of union – the relative area overlap
- For each polygon in I, find the maximum relative area overlap
- Global RAO for I is the average of the maximum relative area overlap for all the polygons in I
- Global RAO can also be calculated as a weighted average, using the area of each polygon in I as the weighting factor

An Example of Relative Area Overlap for Pairs of Polygons

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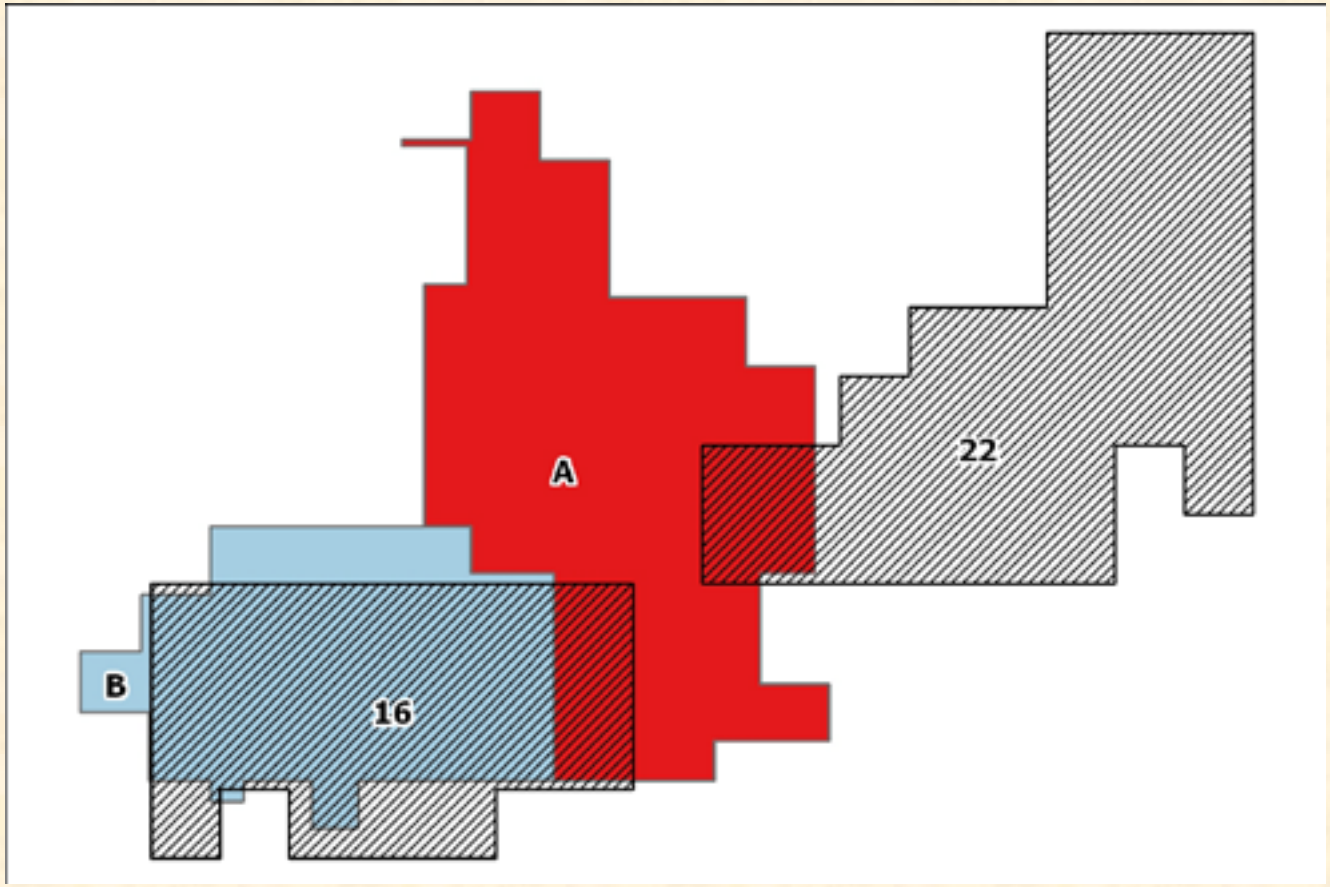

Relative Area Overlap for polygon pairs

A : 16 = 0.05	A : 22 = 0.04
B : 16 = 0.37	B : 22 = 0.00

Testing the Significance of the RAO Statistic

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- Monte Carlo randomisation: create a set of alternative, randomly generated partitions with the same number of polygons and the same footprint as I
- Calculate the RAO statistic for each of the random partitions, then rank the results together with those from the original data to obtain the significance (p) values
- Maruca & Jacquez use randomly generated Voronoi (Thiessen) polygons for their alternative partitions
- Two issues with this approach:
  - Predicated on a null hypothesis of complete spatial randomness (CSR)
  - Voronoi polygons often do not adequately reflect the shapes of polygons mapping real spatial phenomena

More Realistic Alternative Partitions and Local Significance Statistics

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- ‘Shuffle’ the polygons in I, randomly moving each polygon to the centroid of another polygon
- Clean and flatten the shuffled polygons to match the footprint of the original set and eliminate ‘sliver’ polygons, then copy UIDs from source set to the randomised set

- Re-using the original polygons means randomised shapes will be more realistic than Voronoi polygons
- Shuffling based on centroids means that each randomised polygon will correspond to a polygon in the original set I
- P-values can be calculated for each polygon in set I, providing a local significance test

Example of Original Polygon Partition and a ‘Shuffled’ Partition

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Clusters of A) Similar Environmental Factors and B) Similar Forms of Settlement Organisation

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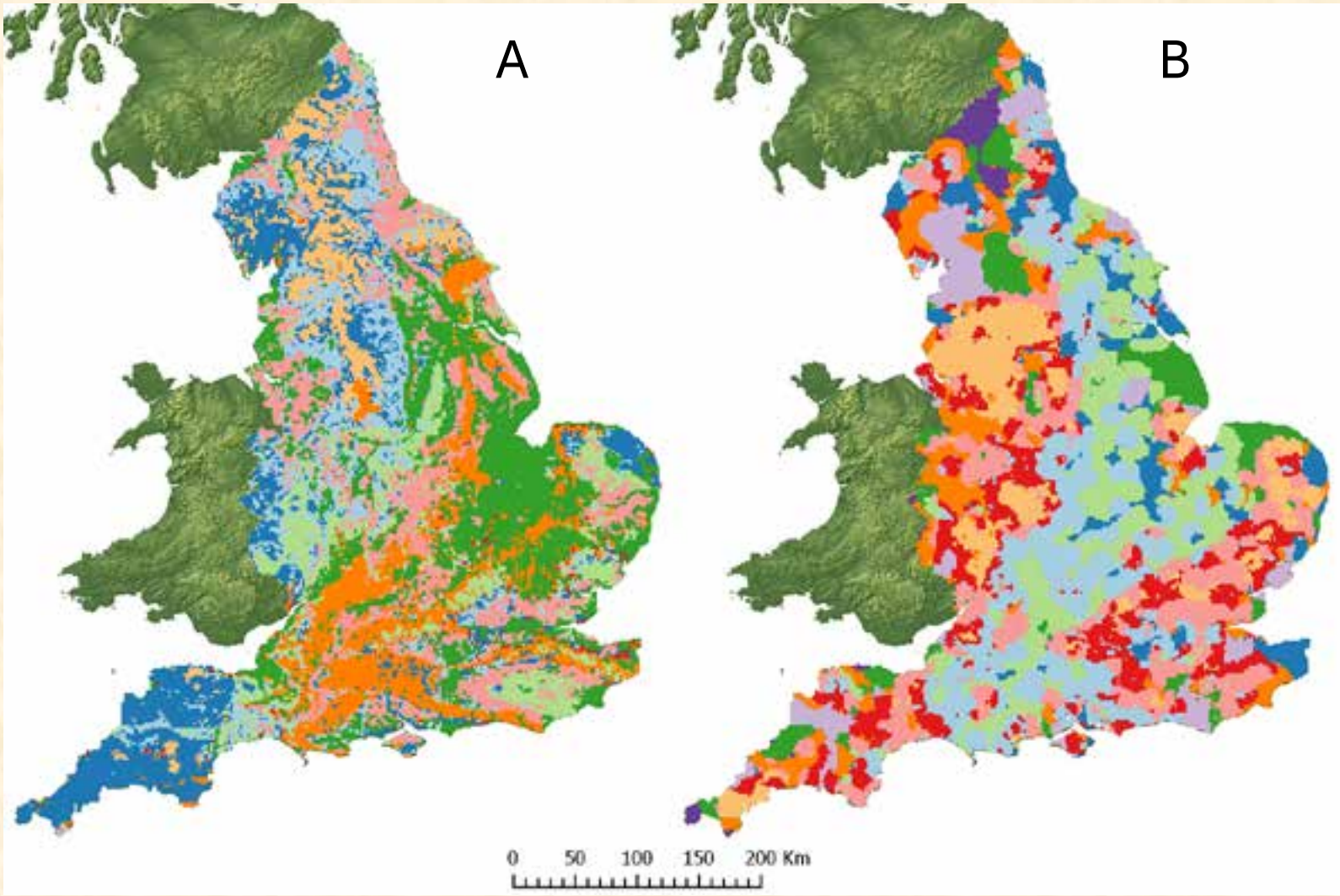

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Global Results

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Comparing clustered (K = 8) environmental factors partition (4,281 polygons) with clustered (K = 10) settlement data partition (1,038 polygons)

	Global RAO	p-value
Unweighted	0.160	0.01*
Weighted	0.174	0.04*

P-values calculated from a null distribution based on 99 randomisations (low number of iterations due to processing time involved)

Local Results

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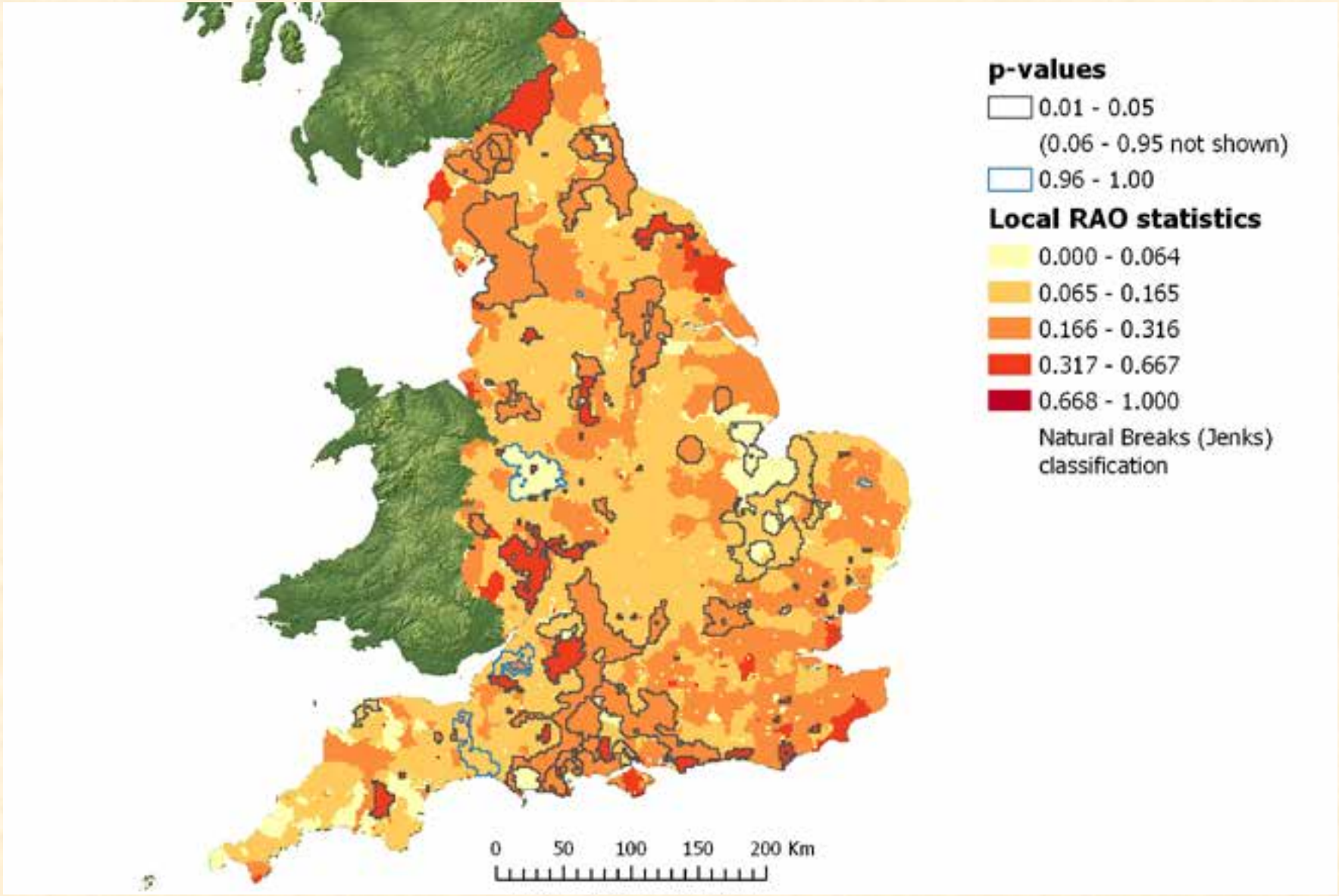

Discussion

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- Global results are significant at $\alpha = 0.05$ level, but overall degree of overlap is quite low

- Locally, about 20% (by area) of the clustered settlement polygons are significant at $\alpha = 0.05$ level, but degree of overlap with clustered environmental factors polygons is often quite low

- Only a few clustered settlement polygons show a statistically significant high degree of overlap

- Even where local overlap is high, this may be the product of chance

Areas for Further Work

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- Methodological:
  - Evaluate more fully the statistical power and sensitivity of the local RAO statistic using simulated data
  - Refine Python scripts (improve speed, error-trapping and remove the need for an ArcInfo/Advanced license) and package them to share with the Esri community
  - Include option to rotate randomised polygons, in addition to 'shuffling'

- Research-oriented:
  - Refine results by using a larger number of randomisations
  - Generate other partitions based on different sets of environmental variables
  - Explore how different clustering methods affect results
  - Ultimately, incorporate 'cultural' variables into the analysis (easier said than done!)

Conclusions

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- Maruca & Jacquez's RAO method can be a very useful tool for evaluating associations between phenomena represented as polygons
- Local version of RAO provides greater insight into where associations (overlaps) are good and where they are not
- Overall, association between clustered environmental factors and clustered historic settlement data is weak
- Results so far suggest that patterns of soils, precipitation, temperature and elevation cannot be said to have strongly influenced patterns of historic settlement organisation in England