Environment and Variation in Historic Settlement Patterns in England

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Background to the Research Problem

• 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

Roberts and Wrathmell’s Provinces, Sub-Provinces and Local Regions
Analytical Approach

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


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

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

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


- 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

- 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

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

- 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

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

Clustering performed using Iso Cluster Unsupervised Classification

$K = 8$ for environmental factors; $K = 10$ for settlement data
Global Results

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

<table>
<thead>
<tr>
<th></th>
<th>Global RAO</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unweighted</td>
<td>0.160</td>
<td>0.01*</td>
</tr>
<tr>
<td>Weighted</td>
<td>0.174</td>
<td>0.04*</td>
</tr>
</tbody>
</table>

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

• 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

• 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

• 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