TerraSeer™
The Wisdom of Where & When™

Articles published in scientific journals confirm the methods behind TerraSeer™ software.

Reprints available from BioMedware, TerraSeer's innovation partner

1) Jacquez, G.M. and D.A. Greiling. 2003. Local Clustering in Breast, Lung and Colorectal Cancer in Long Island, New York. *International Journal of Health Geographics 2:3*.

2) Jacquez, G.M. and D.A. Greiling. 2003. Geographic Boundaries in Breast, Lung and Colorectal Cancers in relation to Exposure to Air Toxics in Long Island, New York *International Journal of Health Geographics 2:4*.

3) Jacquez, G.M., W.A. Marcus, R. Aspinall, and D.A. Greiling. 2002. Exposure assessment using high spatial resolution hyperspectral (HSRH) imagery. *Journal of Geographic Systems* 4: 1-14.

3) Maruca, S.L., and G.M. Jacquez. 2002. Area-based tests for association between spatial patterns. *Journal of Geographic Systems* 4 (1): 69-83.

5) M-J. Fortin, G.M. Jacquez, and B. Shipley. 2002. Computer intensive methods. Encyclopedia of Environmentrics. A.H. El-Shaarawi and W.W. Pie John Wiley & Sons, Ltd, Chichester, 2002

6) Meliker, J.R., J.O. Niragu et al. 2001. Spatial clustering of emergency department visits by asthmatic children in an urban area: south-western Detroit, Michigan. *Ambulatory Child Health* 7: 297-312. (This project used the development version of ClusterSeer, known as GeoMed.)

7) Hall, K.R. and S.L. Maruca. 2001. Mapping a forest mosaic: a comparison of vegetation and bird distributions using geographic boundary analysis. *Plant Ecology*. 156 (1): 105-120

8) Jacquez, G.M., S. Maruca, and M.-J. Fortin. 2000. From fields to objects: a review of geographic boundary analysis. *Journal of Geographic Systems* 2: 221-41.

9) Jacquez, G.M., and L.A. Waller. 2000. The effect of uncertain locations on disease cluster statistics. In: *Quantifying spatial uncertainty in natural resources: theory and applications for GIS and remote sensing*. H.T. Mowrer and R.G. Congalton, eds. pp. 53-64.

10) Fortin, M.-J., and G.M. Jacquez. 2000. Randomization tests and spatially autocorrelated data. *Bulletin of the Ecological Society of America* 81: 201-5.

11) Jacquez, G.M. and J.A. Jacquez. 1999. Disease clustering for uncertain locations. In: *Disease mapping and risk assessment for public health.* A.B. Lawson, A. Biggeri, D. Bohning, E. Lesaffre, J.-F. Viel, and R. Bertollini, eds. New York: John Wiley & Sons.

12) Long, A., M. Wilson, G. Jacquez, and L. Estberg. 1999. The GeoMed project: GIS and spatial/temporal statistics in public health. In: *Proceedings of the International Society for Photogrammetry and Remote Sensing* Volume 17 6W7. L. Mussio, B. Crippa, and G. Forlani, eds. London: RICS Books. pp. 299-305.

13) Jacquez, G. M. and S. L. Maruca, 1998, Geographic boundary detection. In: *Proceedings of the 8th International Symposium on Spatial Data Handling.* T.K. Poiker and N. Chrisman, eds. International Geographical Union. pp. 496-509.

14) Fortin, M.-J., P. Drapeau, and G.M. Jacquez. 1996. Quantification of the spatial co-occurrences of ecological boundaries. *Oikos* 77: 51-60.

15) Jacquez, G. M., 1995, The map comparison problem: Tests for the overlap of geographic boundaries. *Statistics in Medicine*, 14, 2343-2361.

Selected Abstracts and summary information

7) Hall, K.R. and S.L. Maruca. 2001. Mapping a forest mosaic: a comparison of vegetation and bird distributions using geographic boundary analysis. *Plant Ecology*. 156 (1): 105-120.

Abstract. Many areas of ecological inquiry require the ability to detect and characterize change in ecological variables across both space and time. The purpose of this study was to investigate ways in which geographic boundary analysis techniques could be used to characterize the pattern of change over space in plant distributions in a forested wetland mosaic. With vegetation maps created using spatially-constrained clustering and difference boundary delineation, we examined similarities between the identified boundaries in plant distributions and the occurrence of six species of songbirds. We found that vegetation boundaries were significantly cohesive, suggesting one or more crisp vegetation transition zones exist in the study site. Smaller, less cohesive boundary areas also provided important information about the patterns of treefall gaps and dense patches of understory within the study area. Boundaries for songbird abundance were not cohesive, and bird and vegetation difference boundaries did not show significant overlap. However, bird boundaries did overlap significantly with vegetation cluster boundaries. Vegetation clusters delineated using constrained clustering techniques have the potential to be very useful for stratifying bird abundance data collected in different sections of the study site, which could be used to improve the efficiency of monitoring efforts for rare bird species.

8) Jacquez, G.M., S. Maruca, and M.-J. Fortin. 2000. From fields to objects: a review of geographic boundary analysis. *Journal of Geographical Systems* 2: 221-41.

Abstract. Geographic boundary analysis is a relatively new approach unfamiliar to many spatial analysts. It is best viewed as a technique for defining objects—geographic boundaries—on spatial fields, and for evaluating the statistical significance of characteristics of those boundary objects. This is accomplished using null spatial models representative of the spatial processes expected in the absence of boundary-generating phenomena. Close ties to the object-field dialectic eminently suit boundary analysis to GIS data. The majority of existing spatial methods are field-based in that they describe, estimate, or predict how attributes (variables defining the field) vary through geographic space. Such methods are appropriate for field representations but not object representations. As the object-field paradigm gains currency in geographic information science, appropriate techniques for the statistical analysis of objects are required. The methods reviewed in this paper are a promising foundation. Geographic boundary analysis is clearly a valuable addition to the spatial statistical toolbox.

This paper presents the philosophy of, and motivations for geographic boundary analysis. It defines commonly used statistics for quantifying boundaries and their characteristics, as well as simulation procedures for evaluating their significance. We review applications of these techniques, with the objective of making this promising approach accessible to the GIS-spatial analysis community. We also describe the implementation of these methods within geographic boundary analysis software: GEM.

Note: GEM is an earlier prototype of BoundarySeer. BoundarySeer software is now available from TerraSeer, Inc.

10) Fortin, M.-J., and G.M. Jacquez. 2000. Randomization tests and spatially autocorrelated data. *Bulletin of the Ecological Society of America* 81: 201-5.

Note: This paper discusses pitfalls in using randomization tests with spatially autocorrelated data. Fortin and Jacquez advocate the use of restricted randomization to maintain spatial autocorrelation at some scales in the analysis. This approach provides a more rigorous test of the hypotheses and more easily interpreted statistical results.

11) Jacquez, G.M. and J.A. Jacquez. 1999. Disease clustering for uncertain locations. In: *Disease mapping and risk assessment for public health*. A.B. Lawson, A. Biggeri, D. Bohning, E. Lesaffre, J.-F. Viel, and R. Bertollini, eds. New York: John Wiley & Sons.

Note: This chapter provides the basis for including location uncertainty in boundary detection procedures.

Location uncertainty is prevalent in geographic data, particularly for aggregated data (regional averages, number of events in a certain area or within a certain time interval). Thus, defining boundaries on data without taking this uncertainty into account gives inappropriate results.

12) Long, A., M. Wilson, G. Jacquez, and L. Estberg. 1999. The GeoMed project: GIS and spatial/temporal statistics in public health. In: *Proceedings of the International Society for Photogrammetry and Remote Sensing* Volume 17 6W7. L. Mussio, B. Crippa, and G. Forlani, eds. London: RICS Books. pp. 299-305.

A grant from the National Cancer Institute established what we call "the GeoMed Project," for the preparation and evaluation of educational modules for teaching spatial analytic theory and methods applied to human health data. The grant provides as well for the development of software to help meet a crucial objective: to promote the use of spatial and temporal statistics in public health

In order to meet this goal, a web-based course has been developed at the University of Michigan in cooperation with Ann Arbor, MI, software company BioMedware, Inc. The course concentrates on statistics for the detection of clusters of health events in space and time, disease surveillance, and the analysis of disease process and pattern. Examples treated in the course and of particular relevance to public health in Africa include malaria, Dengue fever, and toxic exposures. A web site serves as a learning resource center of materials related to the course, and to spatial analysis in general, providing a wealth of material on software statistical techniques and example applications which visitors may find useful. The web site continues to develop and improve as we reach the halfway point on the project.

In this paper we illustrate and demonstrate the various components of the project, course, site and software, showing how one may make the best use of the materials we have assembled.

Note: the GeoMed software is a prototype version of ClusterSeer, soon to be available from TerraSeer, Inc.

14) Fortin, M.-J., P. Drapeau, and G.M. Jacquez. 1996. Quantification of the spatial co-occurrences of ecological boundaries. *Oikos* 77: 51-60.

Abstract. In this paper we investigate the spatial relationships between vegetation boundaries and environmental boundaries from a second growth forest in southwestern Quebec, Canada. Four statistics that quantify the amount of direct spatial overlap and the mean minimum distance between boundaries are introduced and used to compute the degree of spatial co-occurrences between boundaries. The significance of these statistics is determined using randomized and restricted permutation tests. Boundaries based on tree species density are found to significantly overlap the locations of boundaries delineated by the environmental data at the study site. Significant overlap is also found using boundaries defined by tree presence-absence data and environmental variables. Vegetation boundaries based on tree species density and on tree presence-absence data are not, however, at the same locations. This suggests that for the study site the two types of vegetation boundaries (tree density and presence-absence) reflect different responses to underlying environmental processes. Vegetation boundaries

determined using species diversity and species richness, although spatially related to the presence-absence boundaries, did not overlap the environmental boundaries. Results of the two permutation tests (randomized and restricted) agree only when the spatial relationship between the two boundary types is strong. Overall, randomization is found to be a more conservative test for detecting boundary spatial relationships, rejecting the null hypothesis of no spatial relationship fewer times than the restricted permutation test.