SPATIAL ANALYSIS IN PRECISION TARGETING FOR INTEGRATED PEST MANAGEMENT: CONCEPTS AND PROCESSES

Richard J. Brenner
USDA-ARS-CMAVE
Gainesville, Florida

The approaching loss of methyl bromide will require development of new, more environmentally acceptable active ingredients, and new strategies to detect and mitigate problems in their incipient stages. In any pest management plan, the likelihood of success will be greatest if interventions are directed when and where the probability of encountering the pest is high. A corollary would imply that we could minimize collateral effects (e.g., environmental contamination) if we avoid applying interventions where likelihood of encounter by the pest is low. Toward the latter goal, we have been developing "precision targeting" as a functional strategy to mitigate pest problems with a system that allows incorporation of independent pest management tools for integrated pest management (IPM). The goal is to develop this concept into a standardized, quantifiable risk assessment process for determining the necessity of interventions and selection of those that will optimize reduced use of pesticides, risk reductions, and cost effectiveness (comparative risk reduction).

Our experience over the past several years suggests that spatial statistical methods provide that necessary framework, so that interventions can be applied precisely and minimally. Entomologists, based on their experience, realize that arthropod distributions are not random but occur in discrete clusters. Transferring this knowledge into a versatile pest management scheme, however, is a challenge. This presentation will describe simple spatial statistical concepts for developing a precision targeting process that defines pest distribution with minimal a priori knowledge of the behavior of the pest, and more importantly, provides practitioners with simple, documentable procedures for reducing pesticide use. All described procedures were done with a combination of two commercially available spatial statistical software packages: SURFER for Windows (ver. 6.04, Golden Software, Golden, CO), and VARIOWIN (ver. 2.2, Springer-Verlag, New York).

Spatial statistical analysis, also known as geostatistics, is a powerful tool developed for mineral exploration to determine the size and value of subsurface deposits based on sampling from the surface. The procedures are designed to characterize and model the spatial relationships from sample data, then use the model to estimate values between sample observations so that the entire mineral deposit can be quantified. Fortunately, biological phenomena also exhibit general tendencies of spatial continuity, and spatial statistical procedures recognize that sample observations may be dependent, and that nonrandom sampling strategies may be more useful. Consequently, spatial analysis measures the extent of dependence in the sample data by evaluating variance as a function of the distance and direction between observations.

Much of spatial statistical analysis is devoted to variography -- the characterization and mathematical modeling of spatial continuity from sample data sets. Procedurally, each observation, with its location identified by positional coordinates, is paired with every other observation. Pairs are then sorted by the distance (lag) separating them. The square of the difference between observations is summed over all pairs similarly separated, and a variogram (also referred to as a semivariogram) is constructed by plotting half the variance against the lag spacing (Fig 1a). This characterization of spatial continuity is used next as a mathematical model to estimate (interpolate) the values at unsampled points (grid nodes) within the area of study, commonly using a process called “kriging” that quantifies the entire distribution of the parameter of interest. Finally, kriged data is used to create isolines of equal parameter density visualized as a 3-dimensional surface plot (Fig. 1b, or as a 2-dimensional contour map (Fig. 1c). This entire process of spatial analysis, therefore, provides a method of determining the value of the asset (minerals), or in our case, the scope and precise location of the problem (insect pest).

As a pest management tool, precision targeting is particularly useful when contour lines are expressed as probabilities (“indicators”) of exceeding a given action threshold (Fig 2). These thresholds are likely to be number of insects per trap, plant or per area of a structure or storage facility. These probability contours provide a means of estimating risks, and risk-reductions associated with proposed interventions (i.e., treatments). Following treatment, subsequent post-interventional re-sampling yields other contour maps that provide a "report card" of efficacy, showing areas of improvement and/or areas of deterioration. Comparisons over time can be made by subtracting probabilities of one date from another, providing a "spatial dynamics index" that reveals the areas of changing distributions, and the relative strength of the changes.

The techniques we have described in these examples provide an objective determination of population distributions that are relatively independent of a technician’s skill level, and provide continuity of observations over time. This approach strengthens application of IPM. Indicator kriging and its associated probability contours provide a tool that can be used in assigning risks and in comparing treatment options. Spatial dynamics indices provide documentation and comparative assessments of changes in insect distributions resulting from IPM interventions. Other presentations will provide specific case studies on applications of spatial analysis and precision targeting to a variety of interventions — some of which can replace treatments in which fumigants have been used traditionally.

Suggested reading:
Brenner, R.J., D.A. Focks, R.T. Arbogast, D.K. Weaver, & D. Shuman. In press. Practical use of spatial analysis in precision targeting for integrated pest management. American Entomologist

Rossi, R.E., D.J. Mulla, A.G. Journel and E. H. Franz. 1992. Geostatistical tools for modeling and interpreting ecological spatial dependence. Ecological Monographs 62(2): 277-314.