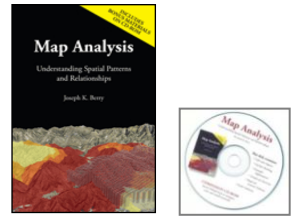
Topic 6 – Summarizing Neighbors



***Map Analysis* book/CD**

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Computer Processing Aids Spatial Neighborhood Analysis

(GeoWorld, October 2005)

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This and the following sections investigate a set of analytic tools concerned with summarizing information surrounding a map location. Technically stated, the processing involves "analysis of spatially defined neighborhoods for a map location within the context of its neighboring locations." Four steps are involved in neighborhood analysis— 1) define the neighborhood, 2) identify map values within the neighborhood, 3) summarize the values and 4) assign the summary statistic to the focus location. Then repeat the process for every location in a project area.

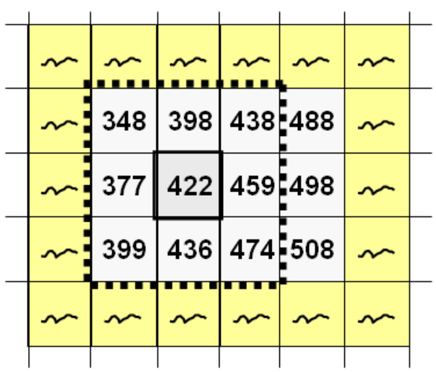
The neighborhood values are obtained by a "roving window" moving about a map. To conceptualize the process, imagine a French window with nine panes looking straight down onto a portion of the landscape. If your objective was to summarize terrain steepness from a map of digital elevation values, you would note the nine elevation values within the window panes, and then summarize the 3-dimensional surface they form.

Now imagine the nine values become balls floating at their respective elevation. Drape a sheet over them like the magician places a sheet over his suspended assistant (who says GIS isn't at least part magical). There it is— surface configuration. All that is left is to ; summarize the lumps and bumps formed by the ghostly sheet by reducing the nine values to a single value characterizing the surface configuration.

Figure 1 shows a small portion of a typical elevation data set, with each cell containing a value representing its overall elevation. In the highlighted 3x3 window there are eight individual slopes, as shown in the calculations on the right side of the figure. The steepest slope in the window is 52% formed by the center and the NW neighboring cell. The minimum slope is 11% in the NE direction.

To get an appreciation of this processing, shift the window one column to the right and, on your own, run through the calculations using the focal elevation value of 459. Now imagine doing that a million times as the roving window moves an entire project area—whew!!!

Elevation Data



Eight Individual Slopes

N = (398 - 422) / (1.00 *100) = 24%
NE = (438 - 422) / (1.41 *100) = 11%
E = (459 - 422) / (1.00 *100) = 37%
SE = (474 - 422) / (1.41 *100) = 37%
S = (436 - 422) / (1.00 *100) = 14%
SW = (399 - 422) / (1.41 *100) = 16%
W = (377 - 422) / (1.00 *100) = 45%
NW = (348 - 422) / (1.41 *100) = 52%

Maximum = 52% Median = 30%
Minimum = 11% Average = 29%

Figure 1. At a location, the eight individual slopes can be calculated for a 3x3 window and then summarized for the maximum, minimum, median and average slope.

But what about the general slope throughout the entire 3x3 analysis window? One estimate is 29%, the arithmetic average of the eight individual slopes. Another general characterization could be 30%, the median of slope values. But let's stretch the thinking a bit more. Imagine that the nine elevation values become balls floating above their respective locations, as shown in Figure 2. Mentally insert a plane and shift it about until it is positioned to minimize the overall distances from the plane to the balls. The result is a "best-fitted plane" summarizing the overall slope in the 3x3 window.

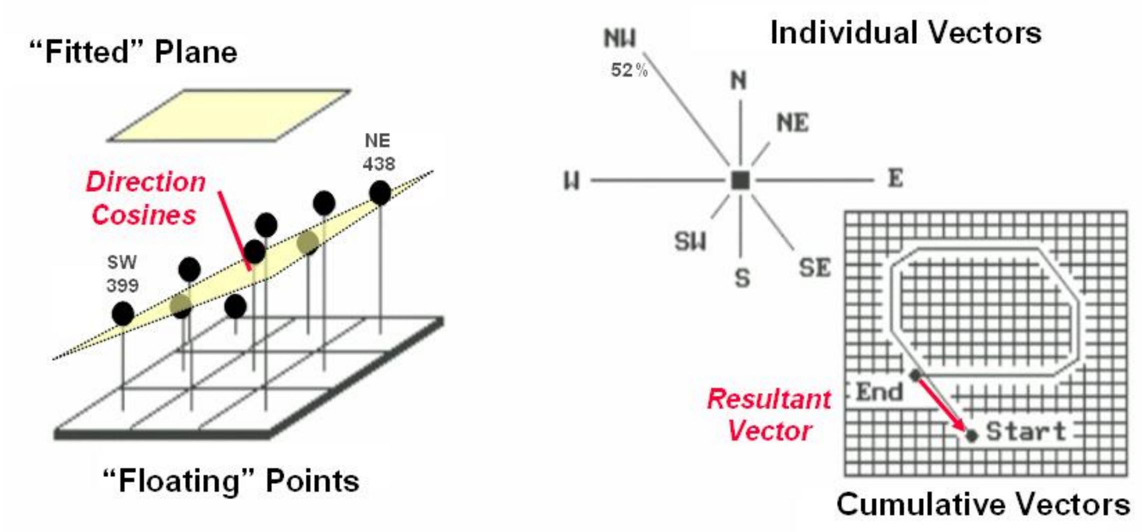


Figure 2. Best-Fitted Plane and Vector Algebra can be used to calculate overall slope.

Techy-types will recognize this process as similar to fitting a regression line to a set of data points in two-dimensional space. In this case, it's a plane in three-dimensional space. There is an intimidating set of equations involved, with a lot of Greek letters and subscripts to "minimize the sum of the squared deviations" from the plane to the points. Solid geometry calculations, based on the plane's "direction cosines," are used to determine the slope (and aspect) of the plane.

Another procedure for fitting a plane to the elevation data uses vector algebra, as illustrated in the right portion of Figure 2. In concept, the mathematics draws each of the eight slopes as a line in the proper direction and relative length of the slope value (individual vectors). Now comes the fun part. Starting with the NW line, successively connect the lines as shown in the figure (cumulative vectors). The civil engineer will recognize this procedure as similar to the latitude and departure sums in "closing a survey transect." The length of the "resultant vector" is the slope (and direction is the aspect).

In addition to slope and aspect, a map of the surface profiles can be computed (see figure 3). Imagine the terrain surface as a loaf of bread, fresh from the oven. Now start slicing the loaf and pull away an individual slice. Look at it in profile concentrating on the line formed by the top crust. From left to right, the line goes up and down in accordance with the valleys and ridges it sliced through.

Use your arms to mimic the fundamental shapes along the line. A 'V' shape with both arms up for a valley. An inverted 'V' shape with both arms down for a ridge. Actually there are only nine fundamental profile classes (distinct positions for your two arms). Values one through nine will serve as our numerical summary of profile.

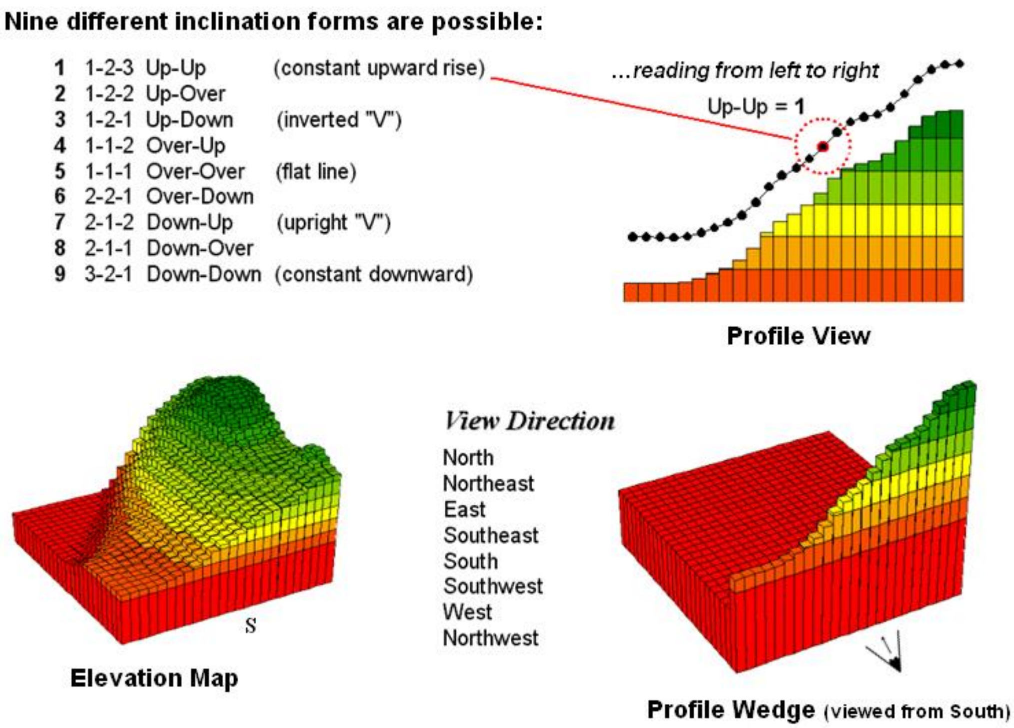


Figure 3. A 3x1 roving window is used to summarize surface profile.

The result of all this arm waving is a profile map— the continuous distribution terrain profiles viewed from a specified direction. Provided your elevation data is at the proper resolution, it's a big help in finding ridges and valleys running in a certain direction. Or, if you look from two opposing directions (orthogonal) and put the profile maps together, a location with an inverted 'V' in both directions is likely a peak.

There is a lot more to neighborhood analysis than just characterizing the lumps and bumps of the terrain. What would happen if you created a slope map of a slope map? Or a slope map of a barometric pressure map? Or of a cost surface? What would happen if the window wasn't a fixed geometric shape? Say a ten minute drive window. I wonder what the average age and income is for the population within such a bazaar window? Keep reading for more on neighborhood analysis.

Milking Spatial Context Information

(GeoWorld, November 2005)

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The previous discussion focused on procedures for analyzing spatially-defined neighborhoods to derive maps of *slope*, *aspect* and *profile*. These techniques fall into the first of two broad classes of neighborhood analysis—Characterizing Surface Configuration and Summarizing map values (see figure 1).

Approach	Description	Example Techniques
Characterizing Surface Configuration	The map values in the roving window are assumed to form a portion of a continuous map surface and **a new map value characterizing the configuration of the implied gradient** is stored for the grid location at the center of the roving window	Slope, Aspect, Profile
Summarizing Map Values	The map values in the roving window are treated numerically and **a new map value summarizing the neighboring values** is stored for the grid location at the center of the roving window	Total, Average, StDev, CoffVar, Maximum, Minimum, Median, majority, Minority, Diversity, Deviation, Proportion, Custom Filters, Spatial Interpolation

Figure 1. Fundamental classes of neighborhood analysis operations.

It is important to note that all neighborhood analyses involve mathematical or statistical summary of values on an existing map that occur within a roving window. As the window is moved throughout a project area, the summary value is stored for the grid location at the center of the window resulting in a new map layer reflecting neighboring characteristics or conditions.

The difference between the two classes of neighborhood analysis techniques is in the treatment of the values—implied *surface configuration* or direct *numerical summary*. Figure 2 shows a direct numerical summary identifying the number of customers within a quarter of a mile of every location within a project area.

The procedure uses a “roving window” to collect neighboring map values and compute the total number of customers in the neighborhood. In this example, the window is positioned at a location that computes a total of 91 customers within quarter-mile.

Note that the input data is a discrete placement of customers while the output is a continuous surface showing the gradient of customer density. While the example location does not even have a single customer, it has an extremely high customer density because there are a lot of customers surrounding it.

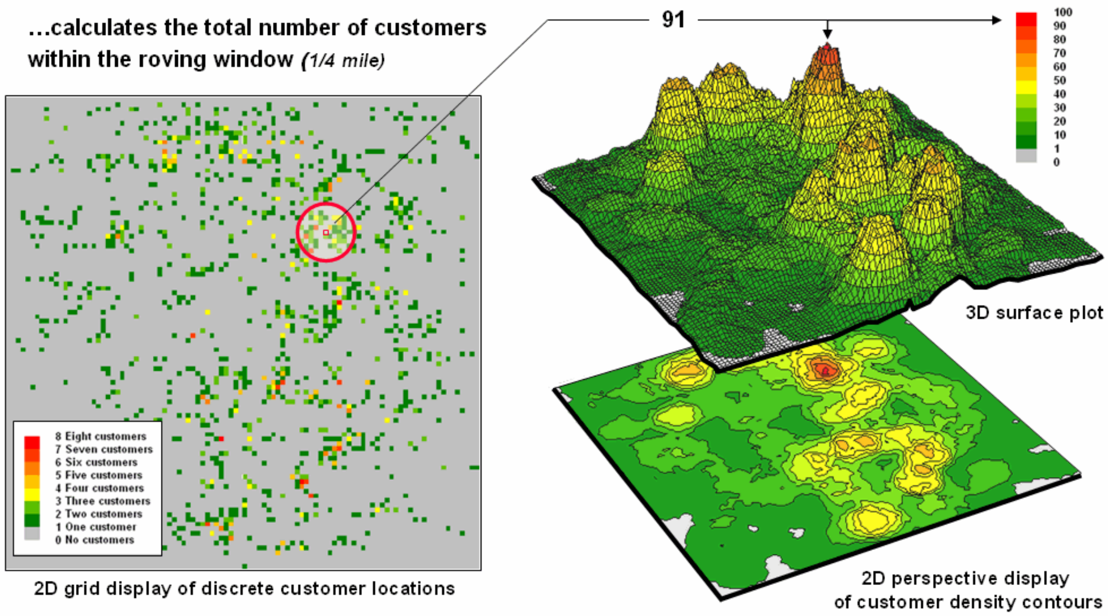

Figure 2. Approach used in deriving a Customer Density surface from a map of customer locations.

The map displays on the right show the results of the processing for the entire area. A traditional vector GIS forces the result into a set of 2D contour intervals stored as discrete polygon spatial objects—1-10 customer range, 10-20, 20-30, etc. The 3D surface plot, on the other hand, shows all of the calculated spatial detail—mountains of high customer density and valleys of low density. An importance difference is that the vector representation aggregates the results, whereas the grid representation contains all of the detailed information.

Figure 3 illustrates how the information was derived. The upper-right map is a display of the discrete customer locations of the neighborhood of values surrounding the "focal" cell. The large graphic on the right shows this same information with the actual map values superimposed. Actually, the values are from an Excel worksheet with the column and row totals indicated along the right and bottom margins. The row (and column) sum identifies the total number off customers within the window—91 total customers within a quarter-mile radius.

This value is assigned to the focal cell location as depicted in the lower-left map. Now imagine moving the "Excel window" to next cell on the right, determine the total number of customers and assign the result—then on to the next location, and the next, and the next, etc. The process is repeated for every location in the project area to derive the customer density surface.

The processing summarizes the map values occurring within a location's neighborhood (roving window). In this case the resultant value was the sum of all the values. But summaries other than *Total* can be used—*Average, StDev, CoffVar, Maximum, Minimum, Median, Majority, Minority, Diversity, Deviation, Proportion, Custom Filters, and Spatial Interpolation*.

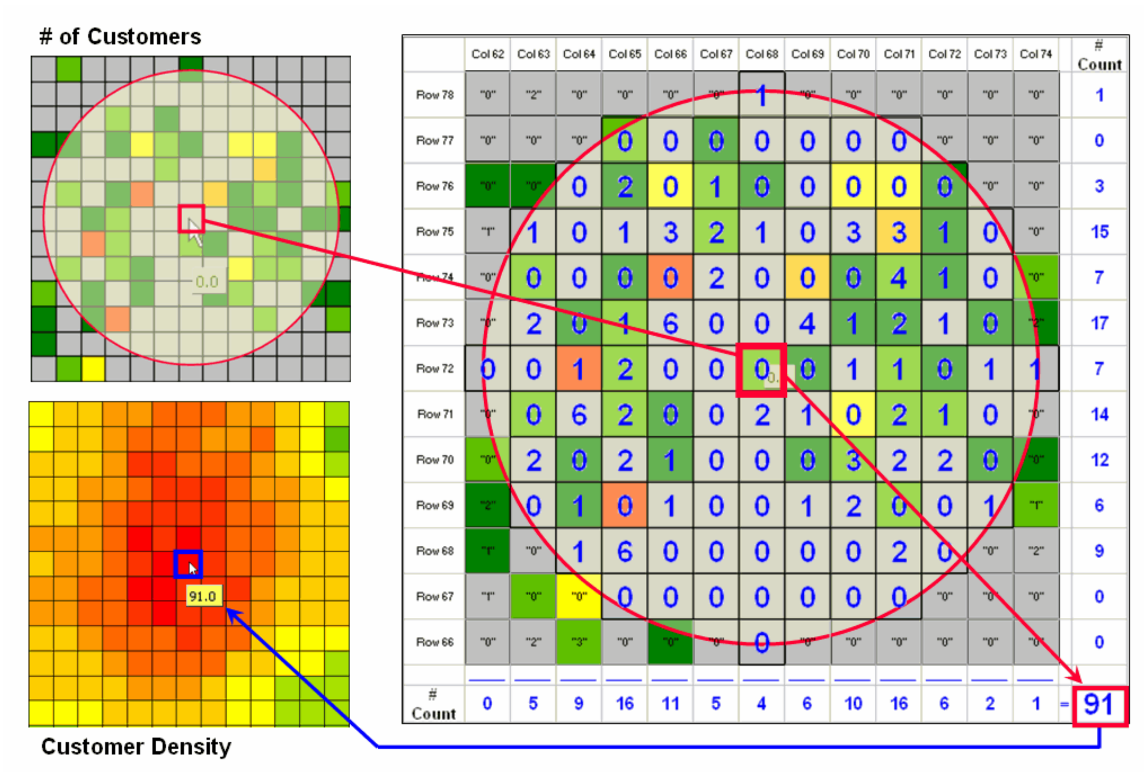

Figure 3. Calculations involved in deriving customer density.

The next section focuses on how these techniques can be used to derive valuable insight into the conditions and characteristics surrounding locations— analyzing their spatially-defined neighborhoods.

Spatially Aggregated Reporting: The Probability is Good

(GeoWorld, January 2006)

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A couple of the procedures used in the wildfire modeling warrant “under-the-hood” discussion neighborhood operations—1) smoothing the results for dominant patterns and 2) deriving wildfire ignition probability based on historical fire records.

Figure 1 illustrates the effect smoothing raw calculations of wildfire risk. The map in the upper-left portion depicts the fragmented nature of the results calculated for a set individual 30m grid cells. While the results are exacting for each location, the resulting "salt and pepper" condition is overly detailed and impractical for decision-making. The situation is akin to the old adage that "you can't see the forest for the trees."

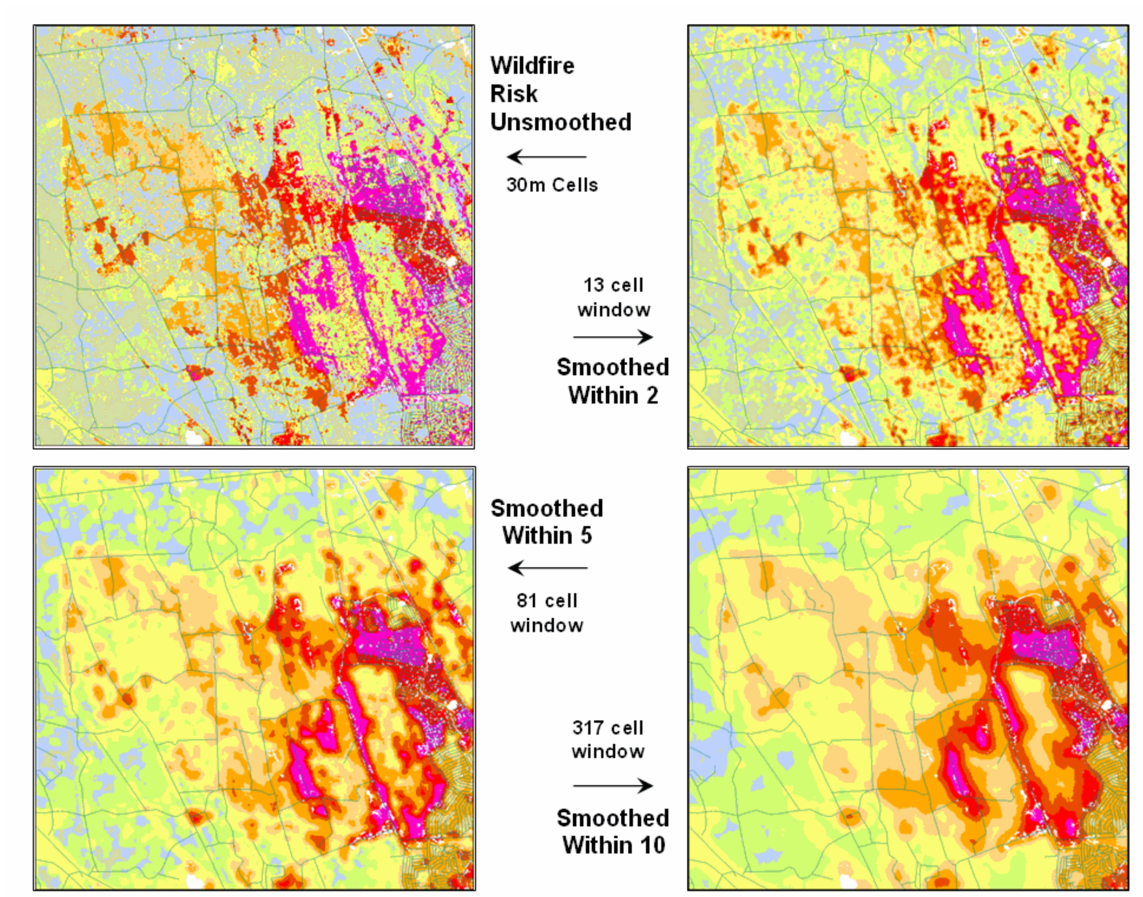

Figure 1. Smoothing eliminates the "salt and pepper" effect of isolated calculations to uncover dominant patterns useful for decision-making.

The remaining three panels show the effect of using a smoothing window of increasing radius to average the surrounding conditions. The two-cell reach averages the wildfire risk within a 13-cell window of slightly more than 2.5 acres. Five and ten-cell reaches eliminate even more of the salt-and-pepper effect. An eight-cell reach (44 acre) appears best for wildfire risk modeling as it represents an appropriate resolution for management.

Another use of a neighborhood operator is establishing fire occurrence probability based on historical fire records. The first step in solving this problem is to generate a continuous map surface identifying the number of fires within a specified window reach from each map location. If the ignition locations of individual fires are recorded by geographic coordinates (e.g., latitude/longitude) over a sufficient time period (e.g., 10-20 years) the solution is straightforward.

An appropriate window (e.g., 1000 acres) is moved over the point data and the total number of fires is determined for the area surrounding each grid cell. The window is moved over the area to allow for determination of the likelihood of fire ignition over an area based on the historic ignition location data. The derived fire density surface is divided by the number of cells in window (fires per cell) and then divided by the number of years (fires per cell per year). The result is a continuous map indicating the likelihood (annualized frequency) that any location will have a wildfire ignition.

The reality of the solution, however, is much more complex. The relative precision of recording fires differs for various reporting units from specific geographic coordinates, to range/township sections, to zip codes, to entire counties or other administrative groupings. The spatially aggregated data is particularly aggravating as all fires within the reporting polygon are represented as occurring at the centroid of a reporting unit. Since the actual ignition locations can be hundreds of grid cells away from the centroid, a bit of statistical massaging is needed.

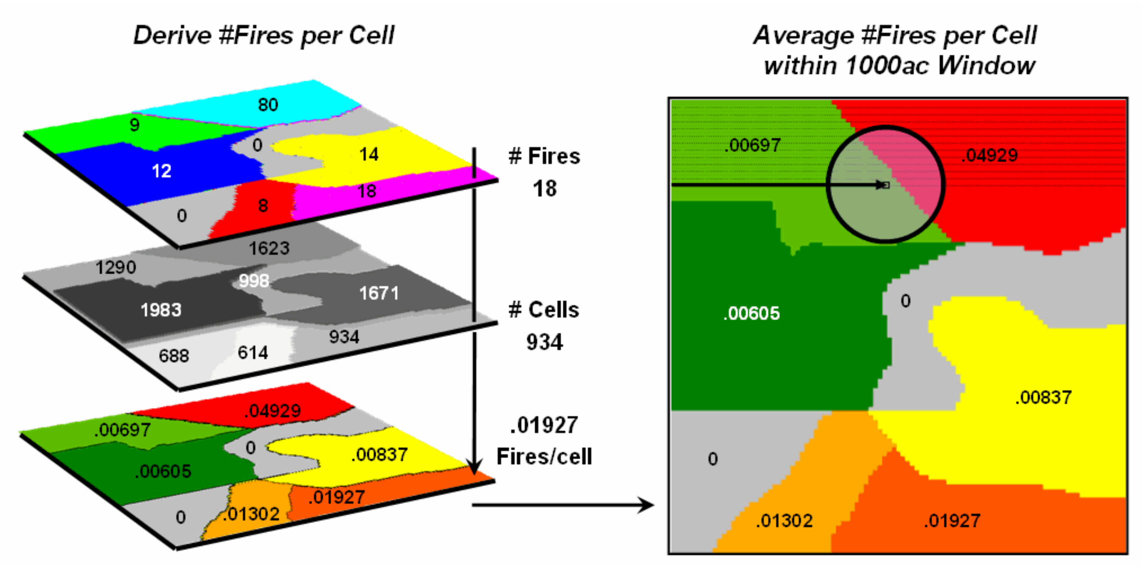

Figure 2. Fires per cell is calculated for each location within a reporting unit then a roving window is used to calculate the likelihood of ignition by averaging the neighboring probabilities.

Figure 2 summarizes the steps involved. The reporting polygon is converted to match the resolution of the grid used by the wildfire risk model and each location is assigned the total number of fires occurring within its reporting polygon (#Fires). A second grid layer is established that assigns the total number of grid cells within its reporting polygon (#Cells). Dividing the two layers uniformly distributes the number of fires within a reporting unit to the each grid cell comprising the unit (Fires/Cell).

The final step moves a roving window over the map to average the fires per cell as depicted on the right side of the figure. The result is a density surface of the average number of fires per cell reflecting the relative size and pattern of the fire incident polygons falling within the roving window. As the window moves from a location surrounded by low probability values to one with higher values the average probability increases as a gradient that tracks the effect of the area-weighted average.

Figure 3 shows the operational results of stratifying the area into areas of uniform likelihood of fire ignition. The reference grid identifies PLSS sections used for fire reporting, with the dots indicating total number of fires for each section. The dark grey locations identify non-burnable areas, such as open water, agriculture lands, urbanization, etc. The tan locations identify burnable areas with a calculated probability of zero. Since zero probability is a result of the short time period of the recorded data the zero probability is raised to a minimum value. The color ramp indicates increasing fire ignition probability with red being locations having very high likelihood of ignition.

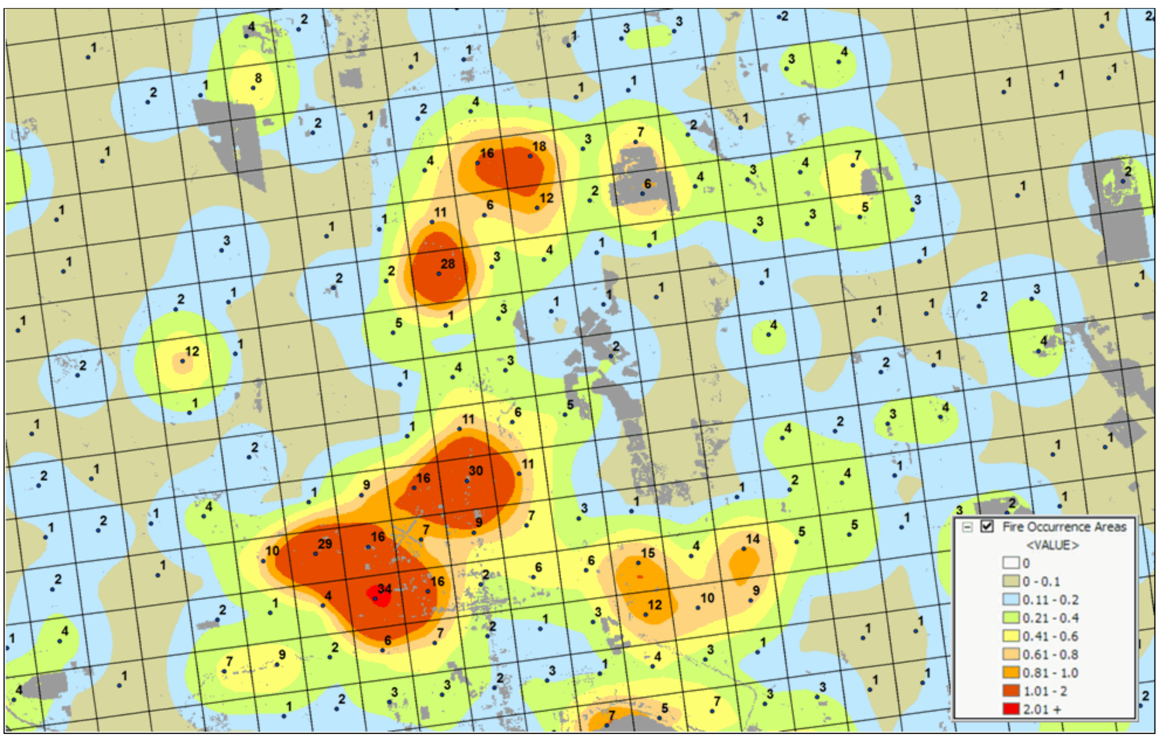

Figure 3. A map of Fire Occurrence frequency identifies the relative likelihood that a location will ignite based on historical fire incidence records.

It is important to note that interpolation of incident data is inappropriate and simple density function analysis only works for data that is reported with specific geographic coordinates. Spatially aggregated reporting requires the use of the area-weighted frequency technique described above. This applies to any discrete incident data reporting and analysis, whether wildfire ignition points, crime incident reports, product sales. Simply assigning and mapping the average to reporting polygons just won't cut it as geotechnology moves beyond mapping.

Author's Note: *Based on Sanborn wildfire risk modeling, www.sanborn.com/solutions/fire_management.htm. For more information on wildfire risk modeling, see GeoWorld, December 2005, Vol.18, No. 12, 34-37, posted at http://www.geoplace.com/uploads/FeatureArticle/0512ds.asp or click here for article with enlarged figures and .pdf hardcopy.*

Further Online Reading: *(Chronological listing posted at **www.innovativegis.com/basis/BeyondMappingSeries/**)*

(Extended Neighborhood Techniques)

Grid-Based Mapping Identifies Customer Pockets and Territories — *identifies techniques for identifying unusually high customer density and for delineating spatially balanced customer territories (May 2002)*

Nearby Things Are More Alike — *use of decay functions in weight-averaging surrounding conditions (February)*

Filtering for the Good Stuff — *investigates a couple of spatial filters for assessing neighborhood connectivity and variability (December 2005)*

(Micro-Terrain Analysis)

Use Data to Characterize Micro-Terrain Features — *describes techniques to identify convex and concave features (January 200)*

Characterizing Local Terrain Conditions — *discusses the use of "roving windows" to distinguish localized variations (February 2000)*

Characterizing Terrain Slope and Roughness — *discusses techniques for determining terrain inclination and coarseness (March 2000)*

Beware of Slope's Slippery Slope — *describes various slope calculations and compares results (January 2003)*

Use Surface Area for Realistic Calculations — *describes a technique for adjusting planimetric area to surface area considering terrain slope (December 2002)*

(Landscape Analysis Techniques)

Use GIS to Calculate Nearby Neighbor Statistics — *describes a technique that calculates the proximity to all of the surrounding parcels of a similar vegetation type (May 1999)*

Use GIS to Analyze Landscape Structure — *discusses the underlying principles in landscape analysis and introduces some example landscape indices (June 1999)*

Get to the Core of Landscape Analysis — *describes techniques for assessing core area and edge characterization (July 1999)*

Use Metrics to Assess Forest Fragmentation — *describes some landscape indices for determining richness and fragmentation (August 1999)*

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