Fit-for-Purpose Weed-Mapping

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I Introduction

Spatial distribution of weeds is characterized using weed density data collected at locations in a field. Different weed-mapping techniques may be used to build different maps of weed density; however the technique chosen must be appropriate to meet research objectives. This study shows five different methods of mapping the same data set and discusses methodological merits and matching of objectives and techniques.

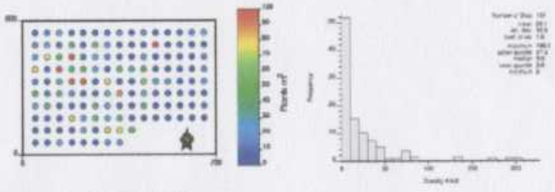
II Methods

Weed density was sampled at 137 locations spaced 50 m apart in a 35 ha field near Saskatoon, Saskatchewan, Canada in 1995. The total number of weeds for all species was counted in 9 ¼ m^2 quadrates on a 3 by 3 grid. The data was mapped using hand contouring, gridding with inverse distance or nearest neighbor, kriging, and simulation to illustrate the merits of each technique.

III Results

The weed distribution from a 35 ha field was skewed, with over 50% of the locations having no weeds. The mean weed density was 22 m^2 with a range of 0 to 198. A large portion of weeds was present in the northwest area of the field (Figure 1).

Figure 1.
Descriptive statistics for a weed distribution from a 35 ha field near Saskatoon, Saskatchewan, Canada that was sampled in 1995. The left map indicates number of weeds counted at 137 sampling locations.



IV Objective for Weed Density Mapping

The utility of weed maps varies and may include:

1. Showing large-scale trends to provide a visual overview of a weed distribution on a field basis.
2. Integrating multiple sources of data by merging a few hard data with soft data to construct a spatial model.
3. Judging the influence of secondary data to reveal spatial trends at different scales.
4. Quantifying weed density over an entire field for a global average.
5. Visualizing variability to understand local variations.
6. Assessing uncertainty to allow an expert to evaluate the risk involved in any decision making.
7. Deciding on locally variable treatment procedures such as variable rate herbicide application.

V Mapping Techniques

Contouring

Contour maps of weeds are a valuable tool for displaying and representing weed densities (Figure 2). This hand contoured map show a series of lines drawn to represent constant data values which gives a smooth representation of the data for understanding large scale trends. The map can mask finer details due to smoothing and is subjective, depending on a weed scientist's experience and judgement for integration of expert knowledge.
Contouring can also be accomplished using commercial software packages, which offer flexibility for data analysis and interpolation. Computer contouring begins by gridding the variable using techniques like splines, kriging or triangulation. Next, the contours are traced through gridded values to reveal weed density trends but they do not replicate short scale variability. Computer contouring is subjective and tends to rely heavily on a user's choice of settings that can mask anomalies and smooth erratic phenomena.

Figure 2.
Mapping technique using hand contouring. Weed density is indicated on the contour lines.

Inverse Distance Type Methods

Weed density can be gridded by classical estimation methods, which weight data according to a mathematical relationship that accounts for distance to nearby data. Two methods that assign all or a portion of the weight to the nearest data include nearest neighbor or inverse distance weighting (IDW), respectively. These methods are illustrated in Figures 3 and 4, respectively. IDW has a tendency to generate "bull's-eye" patterns of concentric contours around the weed density sampling location (Figure 3). When data are sparsely sampled, nearest neighbor is ineffective in extrapolating the data where there are no weeds (Figure 4).

Figure 3.
Mapping technique using inverse distance weighting (IDW). Weed density is indicated by the same colors used in Figure 1.

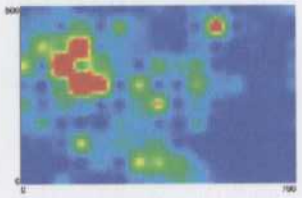
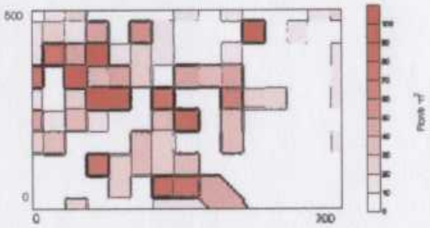


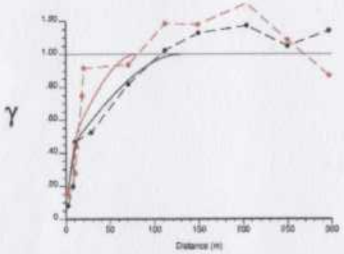
Figure 4.
Mapping technique using nearest neighbor.



Kriging/Simulation

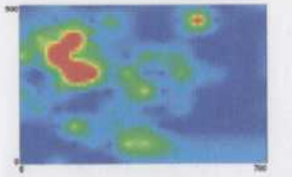
Kriging and simulation are mapping techniques that require a variogram in deriving weights for mapping. Directional variograms for the weed distribution are shown in Figure 5. The maximum direction of continuity has an effective range of approximately 150 m (black line) while the minimum direction of continuity has a range of 80 m (red line).

Figure 5.
Variogram model used in kriging and simulation mapping techniques. The solid lines represent the fitted model whereas the dashed lines with the dots is the experimental model.



Kriging relies on least squares to produce unbiased estimates that minimize the difference squared between the estimated and true value. Figure 6 illustrates the appropriateness of kriging for visualizing trends. Weed density sampling locations are widely spaced, hence the smoothing of the map. The northeast corner of the field had one high weed density value, which resulted in the red area on the map.

Figure 6.
Weed densities mapped using kriging. Weed density is indicated by the same colors used in Figure 1.



Simulation

Variability is expected in biological data, and unique or smooth maps are unrealistic. Simulation captures the uncertainty of weed densities and Figure 7 provides 3 alternative numerical models or realizations that mimic this uncertainty. An average of 101 realizations of this weed distribution is shown in the lower right corner in Figure 7. This realization is very similar to the kriged map in Figure 6. These different realizations are used for risk-quantified decision making in herbicide application rate maps.

Figure 7.
Mapping technique using simulation. These maps represent 3 different simulated maps along with an average of 101 maps in the lower right corner. Weed density is indicated by the same colors used in Figure 1.

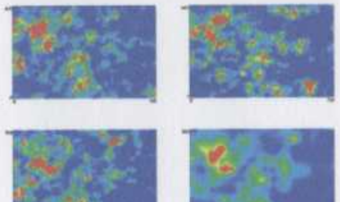


Table 1.
Suitability of mapping techniques in meeting the objectives of research studies.

	Large scale trends	Integrate Secondary data	Influence of secondary data	Quantify weed density	Visualize Variability	Assess Uncertainty	Decision making
Hand Contouring	Green	Green	Yellow	Green	Red	Red	Yellow
Computer Contouring	Green	Yellow	Red	Green	Red	Red	Red
IDW	Yellow	Yellow	Red	Green	Red	Red	Red
Kriging	Yellow	Green	Green	Green	Red	Red	Yellow
Simulation	Red	Green	Green	Yellow	Green	Green	Green

Green-apprpriate
Yellow-could be used but not ideal
Red-inappropriate

VI Conclusions

Rarely are there enough data to provide reliable statistics; however, geostatistical techniques allow characterization of spatial variability and can be used to facilitate decision making. Table 1 indicates the suitability of mapping techniques to meet the objectives of research studies. Cost, timeliness and convenience of obtaining weed data may limit what is measured for analysis. Secondary information from remote sensing data such as elevation may mitigate these issues and help infer spatial statistics since they are more densely sampled. Kriging and simulation allow the incorporation of secondary data where local knowledge is limited.

While grid sampling is commonly used and relatively easy to implement, goals of a study may require different sampling methods to provide a more complete picture of the spatial and biological relationships of weeds. For example, nested and regular sampling will provide characterization of the short-scale variability for locally-varying maps as well as provide coverage for large trends.

For further information, please contact:
ty.faechner@gov.ab.ca or Ai-geostats. 2001. Ai-geostats: The central server for GIS & spatial statistics on the internet. http://www.ai-geostats.org Accessed January 31, 2001.