Line Intersect Sampling Tool (LIST):
A GIS-based tool for Spread Analysis

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1. Introduction

The spread of broad-scale disturbances such as bushfires vary over time and across space. A better understanding of bushfire spread behaviour (e.g. direction, rate of spread and final extent) is important for both long-term planning and effective suppression strategies. A range of models (physical, mathematical and empirical) have been developed for this purpose (Perry, 1998; Sullivan, 2009). For the latter, the aim is to estimate the parameters of a statistical model to predict the probability of bushfire spread in a given direction (Cheney et al., 1998). This first requires identification of a set of potential drivers of bushfire spread, and then tests of their relative importance to influencing the likelihood of spread. This can be established using regression analysis to test for correspondence between spread data and the potential driver variables. To do so requires sampling driver variables along a line orientated in the direction of spread from the boundary of a bushfire at one time interval to its subsequent boundary at the next time interval.

Currently, there are many commercial and open source GIS softwares available which provide options for random point sampling of spatial data. For example, ArcGIS includes a random point generator and various plug-ins are available (i.e., the Sampling Design tool in Hawth's Analysis Tools), MapInfo offers a random number function (RND), and GRASS includes the v.random function. However, random sampling of a spreading phenomenon requires a line-sampling or area-sampling method. Line intersect sampling has previously been implemented in GIS to estimate population density with in a fixed geographic region (Simon, 2006), and for accuracy assessment of map boundaries with respect to ground measurement (Skidmore et al., 1992). In neither of these examples was a temporal dimension incorporated. Further, line intercept sampling has not been used for spread analysis and currently no GIS tool exists to allow random directional sampling of disturbance progressions maps. This paper introduces a new GIS-based tool developed to address this need called the Line Intersect Sampling Tool (LIST).

2. LIST

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LIST is a user-friendly ArcGIS tool developed in Python for creating random line sample transects for progression datasets (Figure 1). As a first step (1), LIST requires a polygon shapefile or feature class that shows the progressive spread of a disturbance whereby each polygon represents the extent covered by the disturbance at a given time step (Figure 2a).

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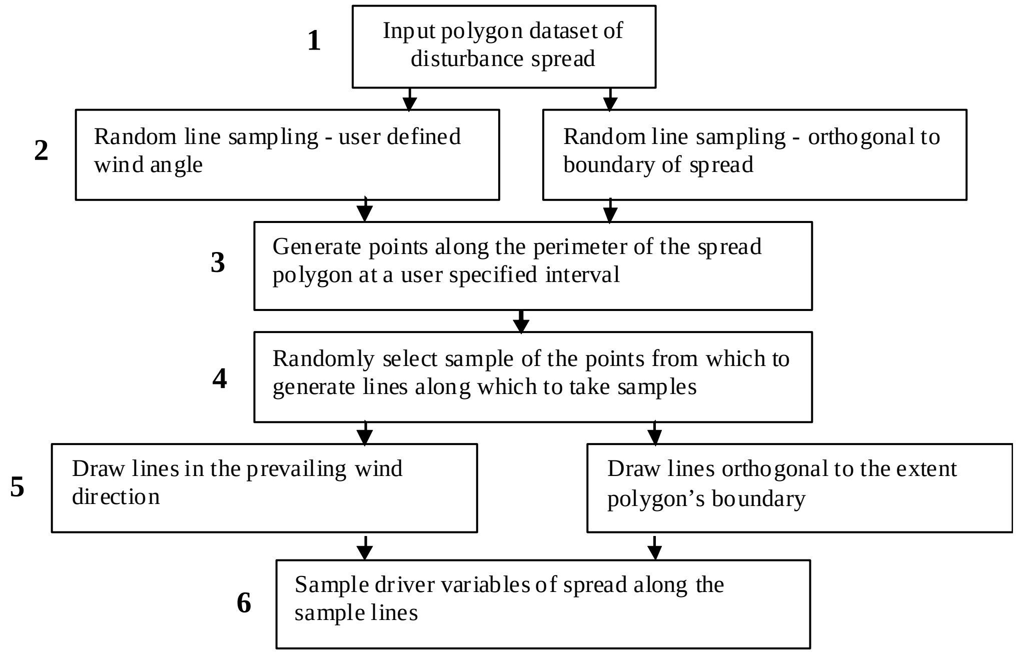
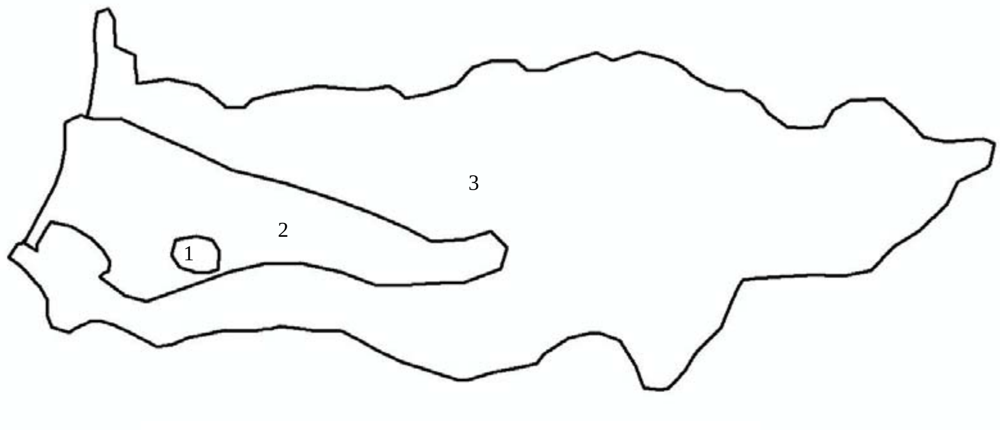


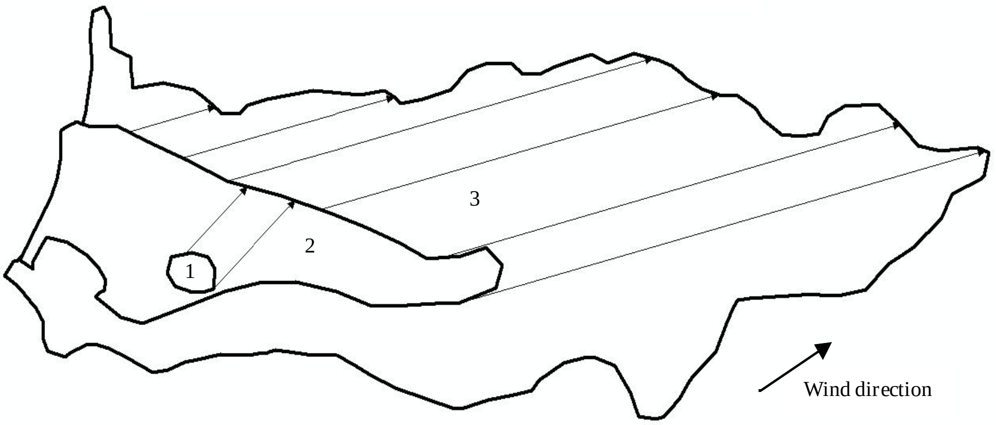
Figure 1. Basic analysis steps in the Line Intercept Sampling Tool (LIST).

The user can then decide whether to construct lines for sampling based on a predetermined dominant wind direction or perpendicular to the spread polygon boundary (2). For example, for a given fire progression dataset (Figure 2a), the former (Figure 2b) would make sense for a bushfire spreading in response to high winds (spreading faster in the prevailing wind direction), while the former (Figure 2c) would be more relevant for a bushfire spreading where winds are minimal (spreading equally fast in all directions). However, as is evident in Figure 2a, even in a high wind situation, a bushfire may still spread in directions other than the dominant wind direction (for example, due to nearby steep terrain). Using a predefined dominant direction will not capture samples along these areas of spread. Future work could address this issue, but in the meantime it would be advisable to take samples using both methods and compare the results.

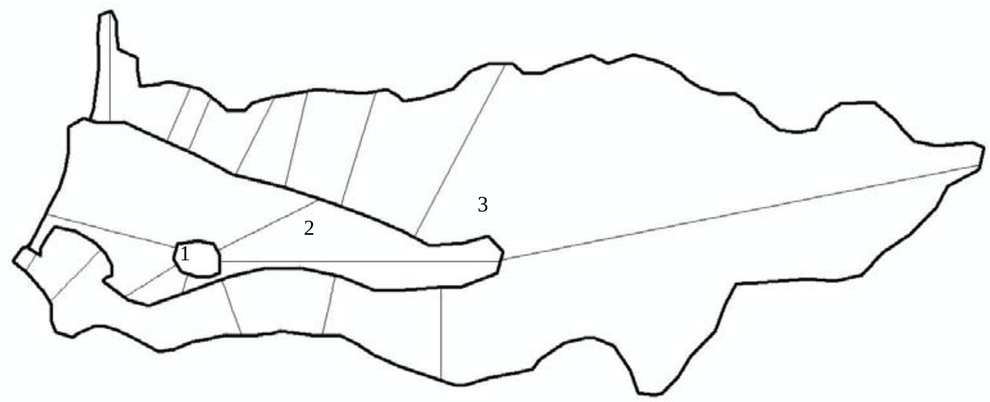
The tool then creates a series of points along the boundary of the initial spread polygon separated by a user-specified distance (3), which represents the spatial density of sampling. LIST takes into account the spatial complexity of polygon boundaries by first using optimised smoothing to remove spikes from the polygons while retaining their original shape, and then by creating points at equal intervals along the polygon boundary. In addition, where necessary, points are moved along complex sections of the polygon boundary to ensure that the lines generated from the points are separated by a threshold distance.



(a) Disturbance Progression Map



(b) Random line sample along wind directions



(c) Random line sample orthogonal to boundary of spread

Figure 2. Sample fire progression dataset for three time periods (initial extent = 1, subsequent extent = 2, final extent = 3) and subsequent random lines for sampling created using LIST.

A random set of points from step #3 (based on a user defined %) are then selected for which to generate random line samples (4). If a predefined wind direction is used, lines are then constructed in this direction only until they reach the boundary of the next spread polygon's extent (Figure 2b). If not, lines are constructed perpendicular to the line segment to which they belong (Figure 2c) (5). Constraints are applied such that each line must begin at a point on the boundary of the initial spread polygon and end at a point on the boundary of the subsequent spread polygon. Once the sample lines are created, the user can extract samples of driver variables for disturbance spread along the lines, and can calculate line statistics such as the minimum, maximum, mean, and standard deviation (6).

3. Case study of a severe bushfire

LIST was tested using data from a severe bushfire that affected the Shoalhaven region (southeast NSW) at Hylands (Lat 35°4'1.20" N, Long 150°27'13.80" E) in December 2001 – January 2002. The dataset consists of 23 days of fire progression data (i.e, 23 fire extent polygons). Preliminary results show that regression models of fire spread developed based on samples obtained using the various line intersect sampling approaches differ considerably. Further work is underway to construct regression models on a daily basis to account for changes in fire weather, conduct sensitivity analysis, and optimize the tool to enable its use for progression data sets with many time intervals (polygons) within a reasonable time frame.

4. Acknowledgements

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5. References

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