Developing an ArcGIS Tool to Investigate and Visualize Correlations Between Land Fragmentation and Southern Pine Beetle Outbreaks

Dahl Winters | Geog 593 Term Project Proposal | 10/4/06

Introduction

It is well-known that land fragmentation can have ecological consequences, although research is still being done to understand the nature of those consequences. Fragmentation is often an indicator of low species diversity, more disturbance, and more edge habitat. It can facilitate the spread of invasive species through an increase in edge habitats, while hindering the dispersal of other species between habitat patches. While the ecological consequences are considerable, the altered species compositions and patch connectivity created by land fragmentation might also have more direct economic consequences, by impacting valuable human resources such as crops or pine plantations. Few studies have been done to analyze what consequences land fragmentation might have on the persistence of pests and pathogens.

Since many people depend on crops and timber for income and a variety of other uses, the effect of land fragmentation on pest and pathogen outbreaks is an important issue. However, most members of the concerned public are unlikely to have a background in ecology, or the skills necessary to perform GIS analyses to answer this question. Thus, the public could benefit from a tool that would allow a user to input their address and learn the relative risk of outbreaks at that location, as obtained from a model of land fragmentation and pest occurrence. Such a tool would help guide simple decision-making, such as which pests and pathogens might be a problem, what and how much pesticide to apply, or whether to apply none at all, if the farm is far enough away from pest sources. By developing a tool that can be easily used by people with a wide range of skill sets, this would help increase awareness of the land fragmentation problem and help open doors to further education on its economic and ecological consequences.

Research Problem

The central problem to be explored is how agricultural and forest pest outbreaks correlate with land fragmentation in North Carolina. The first part of this project will consist of developing a simple model of land fragmentation and susceptibility for a single study organism, *Dendroctonus frontalis*, the Southern Pine Beetle (SPB). This insect species is a major pest of pine trees, and responsible for some of the largest tree losses of any insect in North Carolina.[1] This model will allow identification of areas where SPB occurrence is highly correlated with land fragmentation, and furthermore, places where it is likely to persist. The second part of this project will be to develop a software tool to bring the model results to forest managers and planning officials.

Data Availability

1. Land Cover Data: This data will be taken from the 2001 National Land Cover Dataset (NLCD 2001), available for free download from the USGS Seamless Data Server.[2] The NLCD 2001 land cover data is derived from 30x30 m resolution Landsat TM imagery. The important land cover classes for this project will be primarily pine and mixed forest, which are SPB habitats, and other non-habitat classes such as hardwood forest, agricultural fields, grassland, and

---

[1] http://www.fs.fed.us/foresthealth/risk_maps/risk_maps.html
[2] http://seamless.usgs.gov/

development (little forest or cropland to support pest populations). Suitable habitat patches for the maintenance of this pest will be derived from this layer.

    2. <u>SPB Requirements and Distribution:</u> To determine the suitability of habitat patches in the land cover dataset for SPB, information about habitat requirements and host plants is required, and can be obtained from the National Agricultural Pest Information System (NAPIS) website. Since the SPB specializes on pine trees, suitable habitat will be restricted to the Pine Forest and Mixed Forest land cover classes of the NLCD 2001 dataset. County-level maps of SPB distribution are also available.[3]

Methodology
The steps to complete this project are as follows:

1) <u>Develop a land fragmentation model</u> using the NLCD 2001 dataset, pest requirements, and pest distribution. This model will be used to identify suitable patches of a minimum size (the default will be 1 acre; the user can change this) for pest outbreaks and pest population persistence. A 50-mile buffer will be created around the state border so that edge counties do not have different fragmentation measures than inner counties due to their edge status.
2) <u>Create a visualization tool</u> to allow users to input their address and see at a 30x30 m scale their SPB risk, given model information about the occurrence of previous outbreaks, proximity to forests that could harbor SPB, and the amount of local pine forest fragmentation. The tool will also allow exploration of the effects different land fragmentation scenarios would have by borrowing concepts from graph theory, the study of networks (see example at right). Overlaid on a geographical map of NC will be a set of graph nodes representing patches that are highly susceptible to SPB infestation because of their high connectivity to susceptible areas. The user can click on graph nodes to see how their local susceptibility is impacted when nodes are added or removed. This will allow the user to investigate what the effect on their pest susceptibility would be if their neighbors changed their land uses—for example, replacing pine plantations with hardwood or mixed forest stands to limit the spread of SPB infestations.
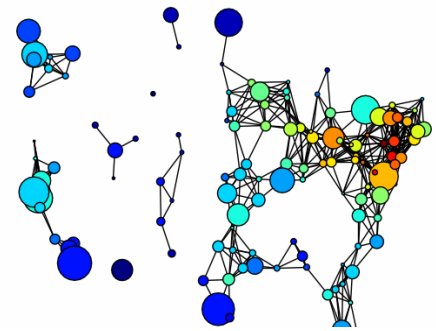
Example of a graph, showing connectivity between major US cities (from the NetworkX web site).

Program Design and Output Format
    The program will be mostly written using Visual Basic for Applications (VBA), and will run from ESRI's ArcGIS 9.1 software package. To implement the graph network feature, some minor editing of existing Python code in the NetworkX package (discussed below) will be required. The output format, shown on the next to last page, will be a map in ArcMap with a left panel that allows selection of which pest susceptibility map to display via radio buttons, and 3 buttons that allow control of the graph display. A right panel will display the user's map of choice, generated from the land fragmentation-pest occurrence model.

    1. <u>Location Input and Verification:</u> An interface will be created for the user to select one of 3 location input methods via radio button. Beneath each method will be a field where they can type the required information. The three location input methods will be 1) street address and

---

[3] http://www.dfr.state.nc.us/health/health_spb.htm and http://www.barkbeetles.org/spb/index.HTML

city, 2) latitude/longitude coordinates, and 3) decimal degrees. If the location is not in NC, a message box will appear for the user to re-enter their location.

2. Main Interface to View SPB Susceptibility Risk: Once the location has been entered, ArcMap will zoom to that location. The default view extent upon zooming in will be 5x5 miles. A susceptibility risk surface will be calculated using information on closest distance to susceptible patches, and the risk surface will be displayed. At all times, a state road layer and city boundary layer (available from the UNC campus network) will be displayed above the susceptibility risk layer, to allow users to orient themselves using familiar streets as landmarks.

3. Using Graphs to View Patch Connectivity and Likelihood of Pest Spread: This program will borrow functions from the NetworkX graph toolkit (written in Python) to assess patch connectivity and the most likely routes of pest spread. NetworkX is freely available for download from the Los Alamos National Laboratory.[4]

There will be a button that will toggle the graph on and off. The graph will be off by default. When it is on, two other buttons below this button will be enabled. These are the Edit Graph and Recalculate Graph buttons. The Edit Graph button simply allows the user to left-click to add nodes, and right-click to remove them. Python code has already been written in NetworkX for adding and removing nodes; this button would just link the user's mouse clicks to these functions. The Recalculate Graph button will be clicked after the user has made all desired changes to the graph. Based on what nodes were added or removed, the program will recalculate the distribution of susceptible patches.

Design Flowchart for the SPB Susceptibility Tool
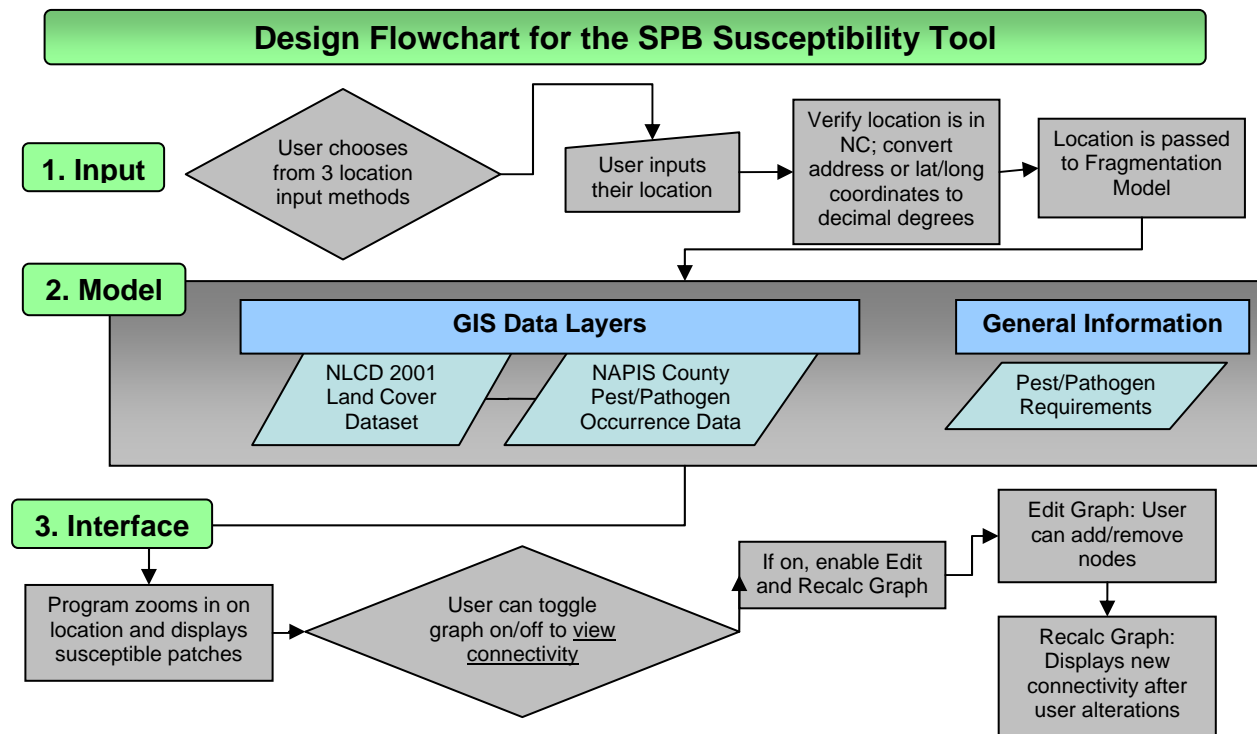
Sketch of Intended Output Format
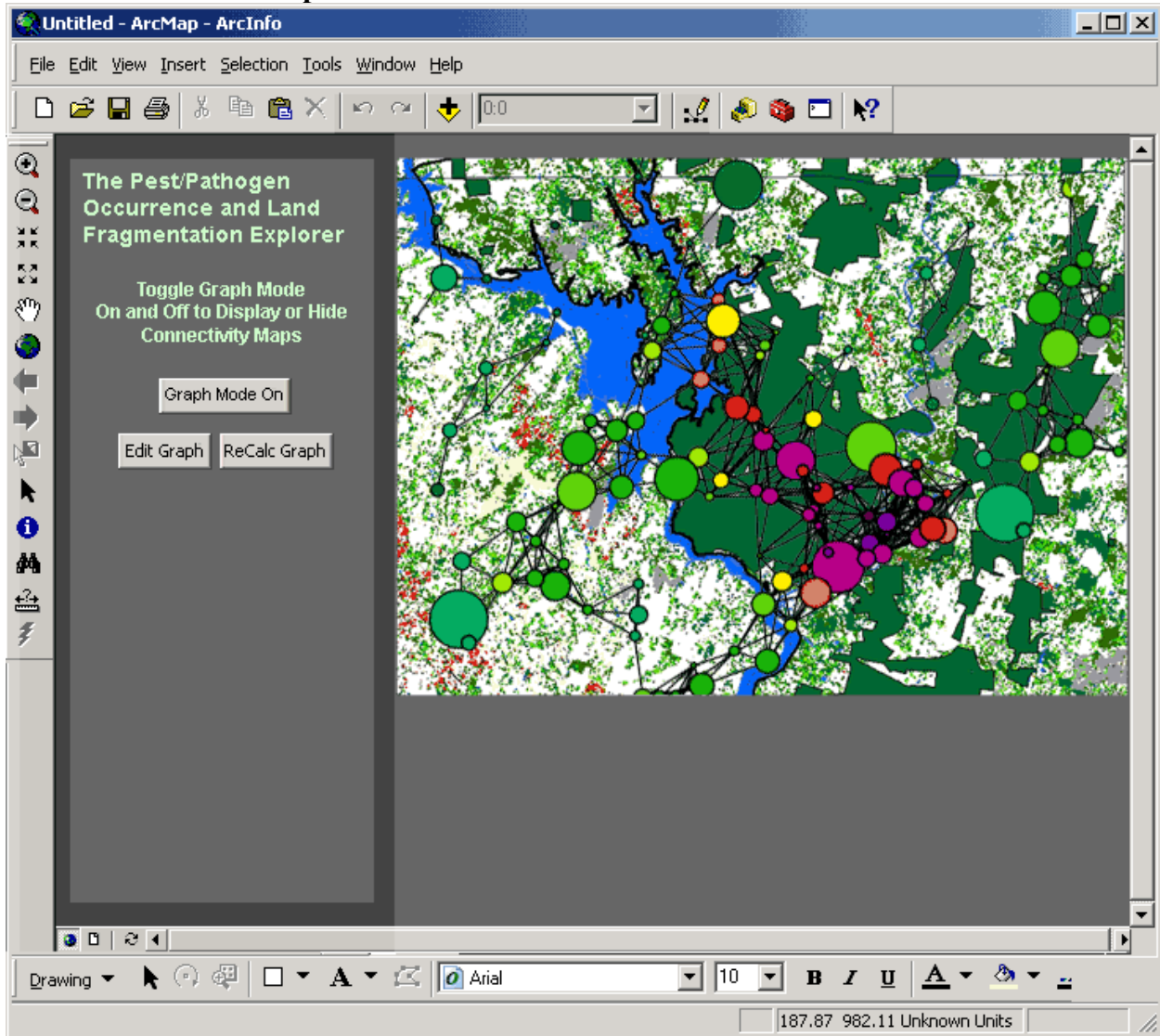
How to Interpret and Use Results

    The greatest usefulness of this tool will be to allow the user to generate and explore what-if scenarios of land use, and the probable outcome of that land use on SPB susceptibility. This tool can also help users manage their pesticide use. If they live in a low susceptibility area, they might not need as much pesticide or other management (forest clearing or thinning) against SPB.

    It is important to remember that this model is intended to be used only a tool for visualizing the impact that local land uses might have on SPB occurrence and persistence. It is not meant to be exact. There are four major sources of uncertainty. The first comes from pixel misclassification errors in the National Land Cover Dataset. Accuracy levels range from 52% for the bare/mine/transitional land cover class to over 90% for the forest classes. The second source of error comes from necessary oversimplification; to make this model a simple one for the user to understand, variables other than land fragmentation that affect SPB occurrence or persistence must be excluded. This is considered an acceptable source of error for this analysis because 1) fragmentation is so prevalent in the North Carolina landscape, and 2) at that large

scale, land cover (i.e. the presence of pine stands) strongly determines where pest populations and outbreaks can occur. The last source of error is perhaps the most significant—it is unknown exactly how land fragmentation might affect SPB occurrence and persistence. To get a better understanding of this, more research will be necessary. It is my hope that this project can serve as an introduction to future dissertation research.