

Developing an ArcGIS Tool to Investigate and Visualize Correlations Between Land Fragmentation and Pest/Pathogen Outbreaks

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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

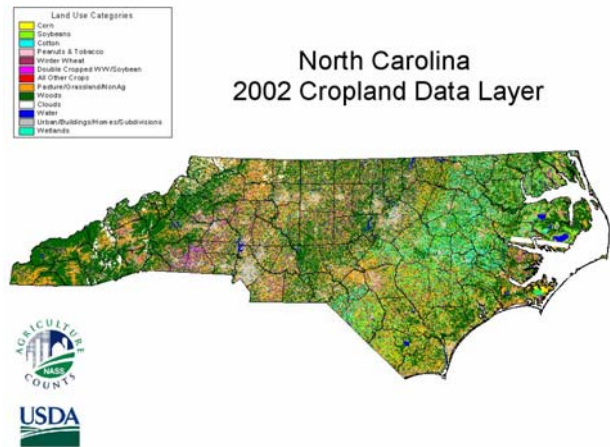
The central problem to be explored is how agricultural and forest pest outbreaks correlate with land fragmentation in North Carolina. The first part of this project will consist of developing a simple model of land fragmentation and susceptibility, for a small number of pest and pathogen types. This will allow identification of areas where pest occurrence is highly correlated with land fragmentation, and furthermore, places where particular pests are likely to persist. The second part of this project will be to develop a software tool, the Pest/Pathogen Occurrence and Land Fragmentation Explorer, to bring the model results to farmers, 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.¹ 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 forest (hardwood, pine, and mixed), agricultural fields, grassland, and development (little forest or cropland to support pest populations). Suitable habitat patches for the maintenance of each pest/pathogen will be derived using a combination of this layer and the following crop distribution layer.

¹ <http://seamless.usgs.gov/>

2. Crop Distribution Data: The Cropland Data Layer for North Carolina (shown at right) comes in DVD format at a cost of \$50, and can be obtained within 1-2 weeks.² This data layer produced by the National Agricultural Statistics Service (NASS) shows the distributions of the 6 most planted crops in NC, at 30x30m resolution for compatibility with the NLCD 2001. It also includes one class for all other crops that has a negligible spatial extent. However, to provide the user with information on what crops might be accounted for by this class, county-level distribution data for 24 crops is available.³



3. Pest/Pathogen Requirements: To determine the suitability of habitat patches in the land cover dataset for each pest/pathogen, information about habitat requirements and host plants is required, and can be obtained from the National Agricultural Pest Information System (NAPIS) website. Since many of these disease agents specialize on particular crops, their potential habitat will likely be restricted to that particular crop class in the Cropland Data Layer, or the Agricultural land cover class of the NLCD 2001 dataset. For forest pests/pathogens, suitable habitat will be restricted to the Pine Forest and Mixed Forest land cover classes of the NLCD 2001 dataset.

4. Pest/Pathogen Occurrence: Most of this data is also available from NAPIS for download. The agricultural insect pests with available distribution maps from this site are listed in the table at right. In addition to those agricultural pests, this project will consider the Southern pine beetle, a major pest of pine trees and responsible for some of the largest tree losses of any insect in North Carolina.⁸ Soybean rust and the soybean cyst nematode will also be considered, since these are both responsible for major soybean losses in NC, which currently produces 80% of US-grown soybeans.⁹

<p>Pests/Pathogens with distribution maps available from NAPIS⁴: Alfalfa weevil <i>Hypera postica</i> Cereal leaf beetle <i>Oulema melanopus</i> Corn rootworm, northern <i>Diabrotica barberi</i> Corn rootworm, western <i>Diabrotica virgifera</i> European gypsy moth <i>Lymantria dispar</i> Sweetpotato weevil <i>Cylas formicarius elegantulus</i></p> <p>Distribution maps available elsewhere: Southern pine beetle <i>Dendroctonus frontalis</i>⁵ Soybean rust <i>Phakopsora pachyrhizi</i> and <i>P. meibomia</i>⁶ Soybean cyst nematode <i>Heterodera glycines</i>⁷</p>

² <http://www.nass.usda.gov/research/Cropland/SARS1a.htm>

³ http://www.nass.usda.gov/Charts_and_Maps/Crops_County/index.asp

⁴ <http://ceris.purdue.edu/napis/maps/stsurvey.html>

⁵ http://www.dfr.state.nc.us/health/health_spb.htm and <http://www.barkbeetles.org/spb/index.HTML>

⁶ <http://ceris.purdue.edu/napis/pests/asbr/>

⁷ http://www.ces.ncsu.edu/depts/pp/notes/Soybean/soy001/img_smap.htm

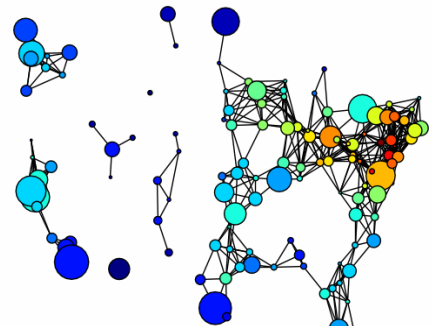
⁸ http://www.fs.fed.us/foresthealth/risk_maps/risk_maps.html

⁹ <http://www.wisc.edu/ncra/impstate-NCERA137.doc>

Methodology

The 4 steps to complete this project are as follows:

- 1) Determine pest requirements, such as host plant types and cold tolerance, that will affect which land cover classes will support the pest. This information is available from NAPIS.
- 2) Obtain pest occurrence data by county. Pest occurrences on NAPIS are usually recorded at the county level, which makes this the analysis unit of choice.
- 3) Develop a land fragmentation model using both the NLCD 2001 dataset and the Cropland Data Layer. 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.
- 4) Create a visualization tool to allow users to input their address and see at a 30x30 m scale their susceptibility to particular pest outbreaks, given model information about the occurrence of previous outbreaks, proximity to cropland that could harbor pests/pathogens, and the amount of local land fragmentation. The tool will also allow exploration of the effects different land fragmentation scenarios would have by theory, the study of networks (see example at right). Overlaid will be a set of graph nodes representing patches that are highly infestation because of their high connectivity to susceptible are graph nodes to see how their local susceptibility is impacted w/ removed. This will allow the user to investigate what the effect would be if their neighbors changed their land uses—for example pine forest between soybean farms to limit the spread of the so



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 App from ESRI's ArcGIS 9.1 software package. To implement the graph minor editing of existing Python code in the NetworkX package (d 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.

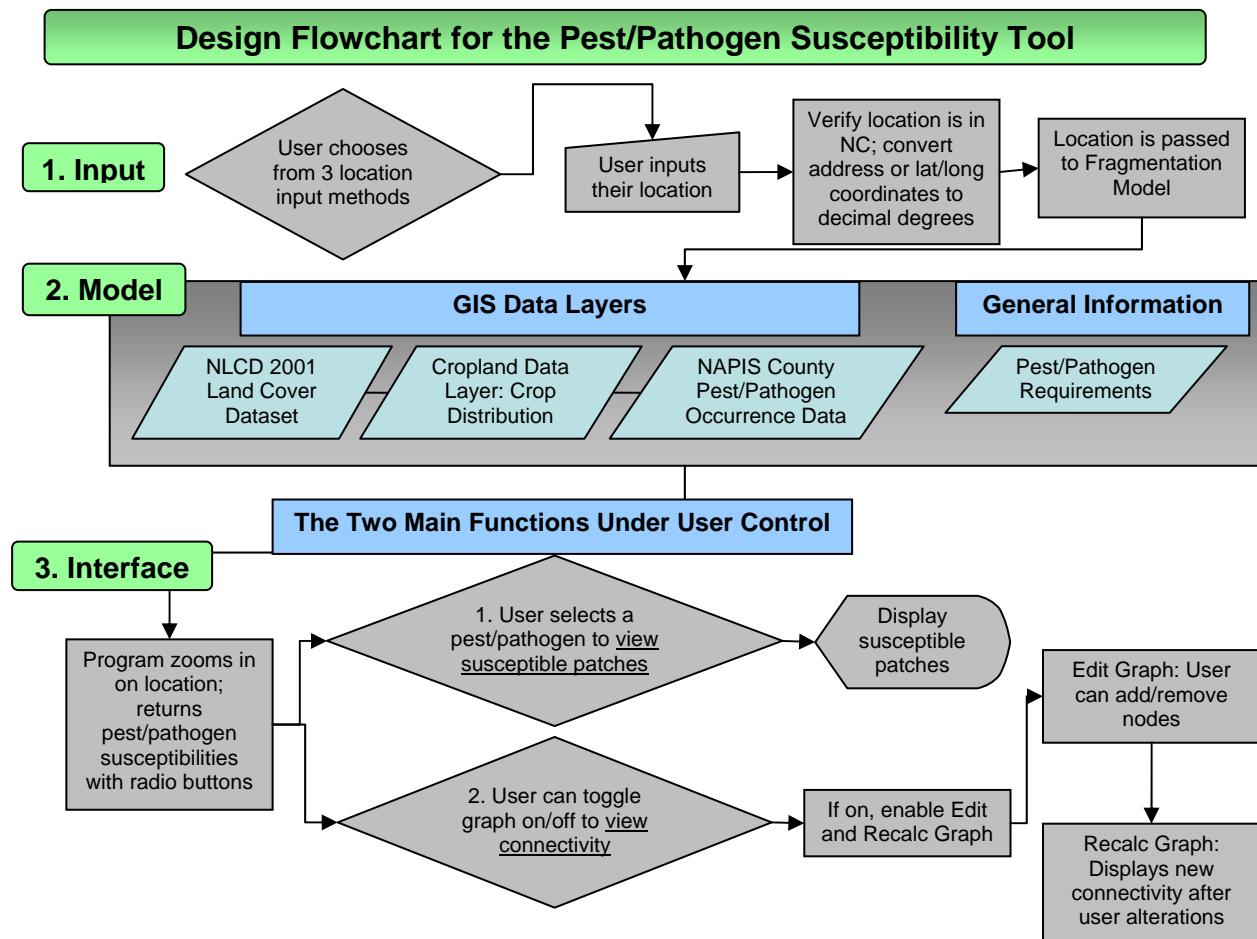
1. Location Input and Verification: An interface will be created for the user to select one of 3 location input methods via radio button. Beneath each method will be a field where they can type the required information. The three location input methods will be 1) street address and city, 2) latitude/longitude 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: Once the location has been entered, ArcMap will zoom to that location. On the left panel of the screen will be a display of the names of all pests likely to be found within the default view extent upon zooming in (5x5 miles). There will be radio buttons to the left of these names, and below each name, a link to take the user to a website for more information on that pest. The user has the option of clicking on a radio button to view susceptible patches for a particular pest within the view extent.

At all times, a state road layer and city boundary layer (available from the UNC campus network) will be displayed on top of any other visible layers, to allow the user to orient themselves using familiar streets as landmarks.

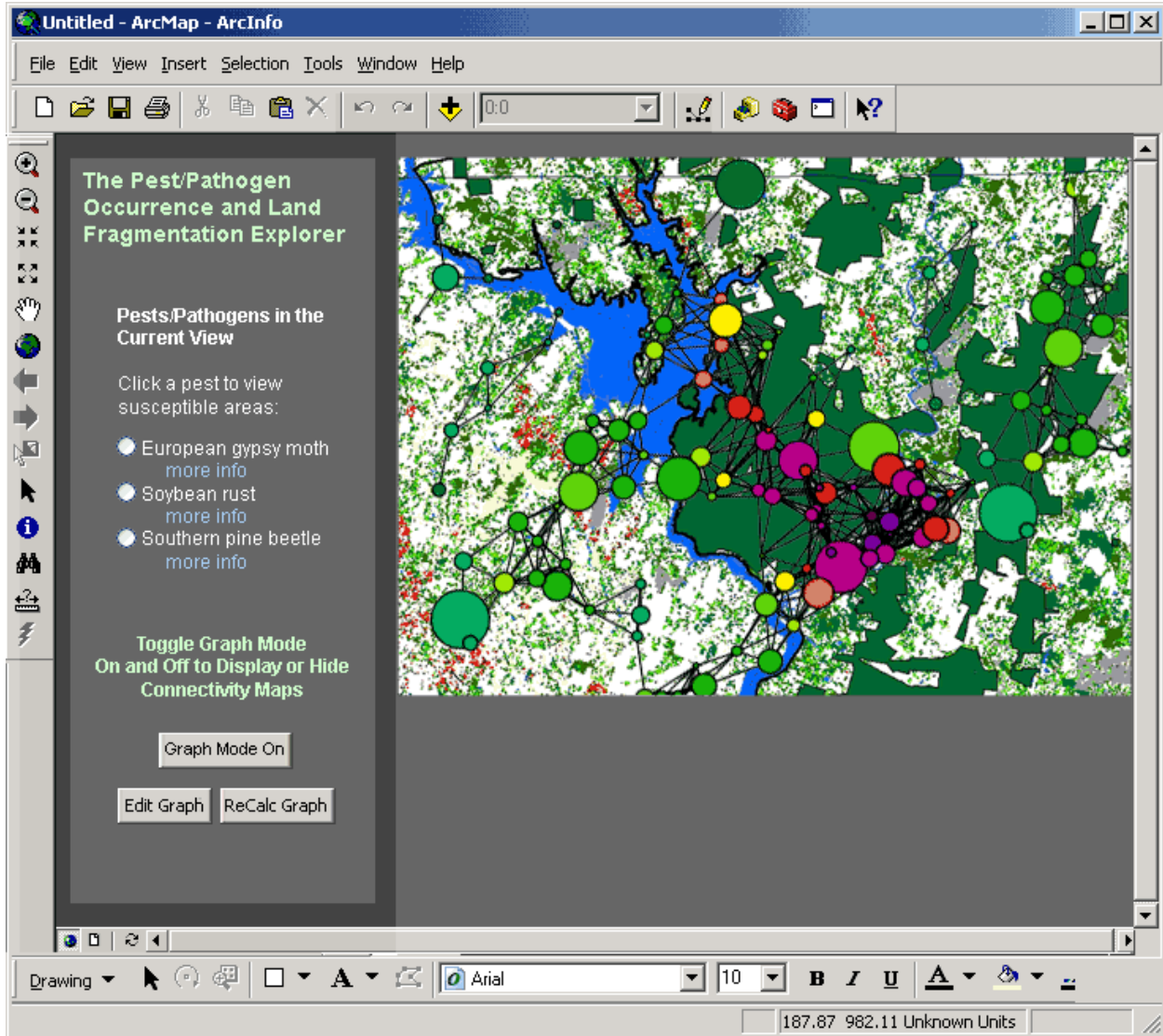
3. Using Graphs to View Patch Connectivity and Likelihood of Pest Spread: This program will borrow functions from the NetworkX graph toolkit (written in Python) to assess patch connectivity and the most likely routes of pest spread. NetworkX is freely available for download from the Los Alamos National Laboratory.¹⁰

Below the list of pest names, 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 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.



¹⁰ <https://networkx.lanl.gov/>

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 pest 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 against a particular pest.

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 pest 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 some of the vegetation classes. The second comes from the Cropland Data Layer, which also has misclassification errors. Accuracy levels are better for this dataset, from 80-90%. The 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 pest occurrence/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 strongly determines where pest populations and outbreaks can occur (limited to agricultural fields, for example). The last source of error is perhaps the most significant—it is unknown exactly how land fragmentation might affect pest 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.