

Probabilistic Commodity-Flow-Based Focusing of Monitoring Activities to Facilitate Early Detection of *Phytophthora ramorum* Outbreaks

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Project Objectives

Through the use of trace-forward information regarding the shipment of *P. ramorum* infected nursery stock provided by the USDA Animal and Plant Health Inspection Service (APHIS), supplemented by commodity flow data from the US Departments of Commerce and Transportation, the analytical techniques and software developed by this project will allow forest health managers to focus their limited resources on areas with the greatest likelihood of new *P. ramorum* infestation and thus more quickly identify newly infested areas, increasing the likelihood of successful intervention before the pathogen crosses the urban-forest interface.



Products

This project produced two deliverables, a technical paper describing the probabilistic techniques used in the analysis along with a comprehensive list of data sources. Examples of the application of the model were also documented.

The second deliverable was an open source software package, written in the Java programming language for portability across hardware and software platforms, that implements the model. Full documentation of the software was provided.

Mathematical Methodology

The goal of the probabilistic model and implementing software is to give the USDA Forest Service an analytical tool to help focus scarce inspection resources on the early detection of *P. ramorum* outbreaks in those parts of North America where the pathogen, which causes Sudden Oak Death (SOD), is not yet endemic. This is accomplished by using partial survey results, along with commodity flow information, to create an ordered list of those sites presently not known to be infected. The list is ordered by likelihood of each site having recently become infected through the importation of infectious nursery stock.

The process of creating this list consists of several stages. In the first stage some subset of vulnerable sites, typically areas east of the Rocky Mountains, are surveyed. The surveyed sites are categorized as being recently infected, very likely to be uninfected, or being a site for which infection status is uncertain. Sites with an uncertain infection status will be treated as though they were not surveyed. The combination of newly infected sites and recently certified clean sites is called an *infection pattern*.

Once newly infected and known clean sites are identified, known potential sources of infectious nursery stock are assigned probabilities of being active sources of infectious nursery stock. In the terminology of probability theory this is a Bayesian process in which the probability of infectious exports assigned to each potential source is updated from some previous value based on the newly observed infection pattern. For example, those sources which happen to send a large amount of nursery stock to newly infected destinations will be assigned a high probability of exporting infectious materials because the new infections must have come from somewhere and the sources sending materials to these destinations are good suspects. Similarly, sources that send large amounts of nursery stock to sites classified as known clean sites will be given a low probability of sending infectious exports because receiving these exports has not resulted in infection.

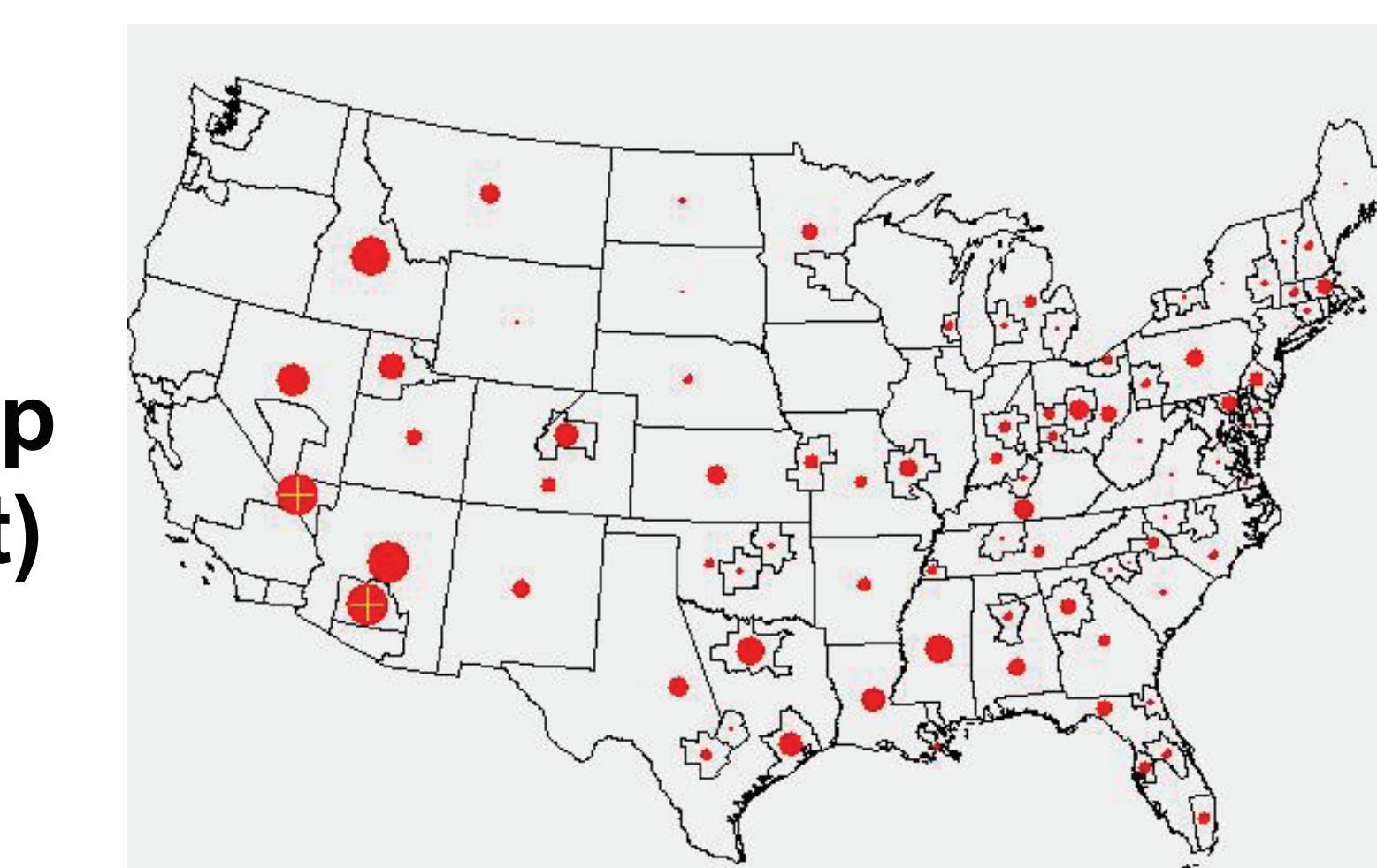
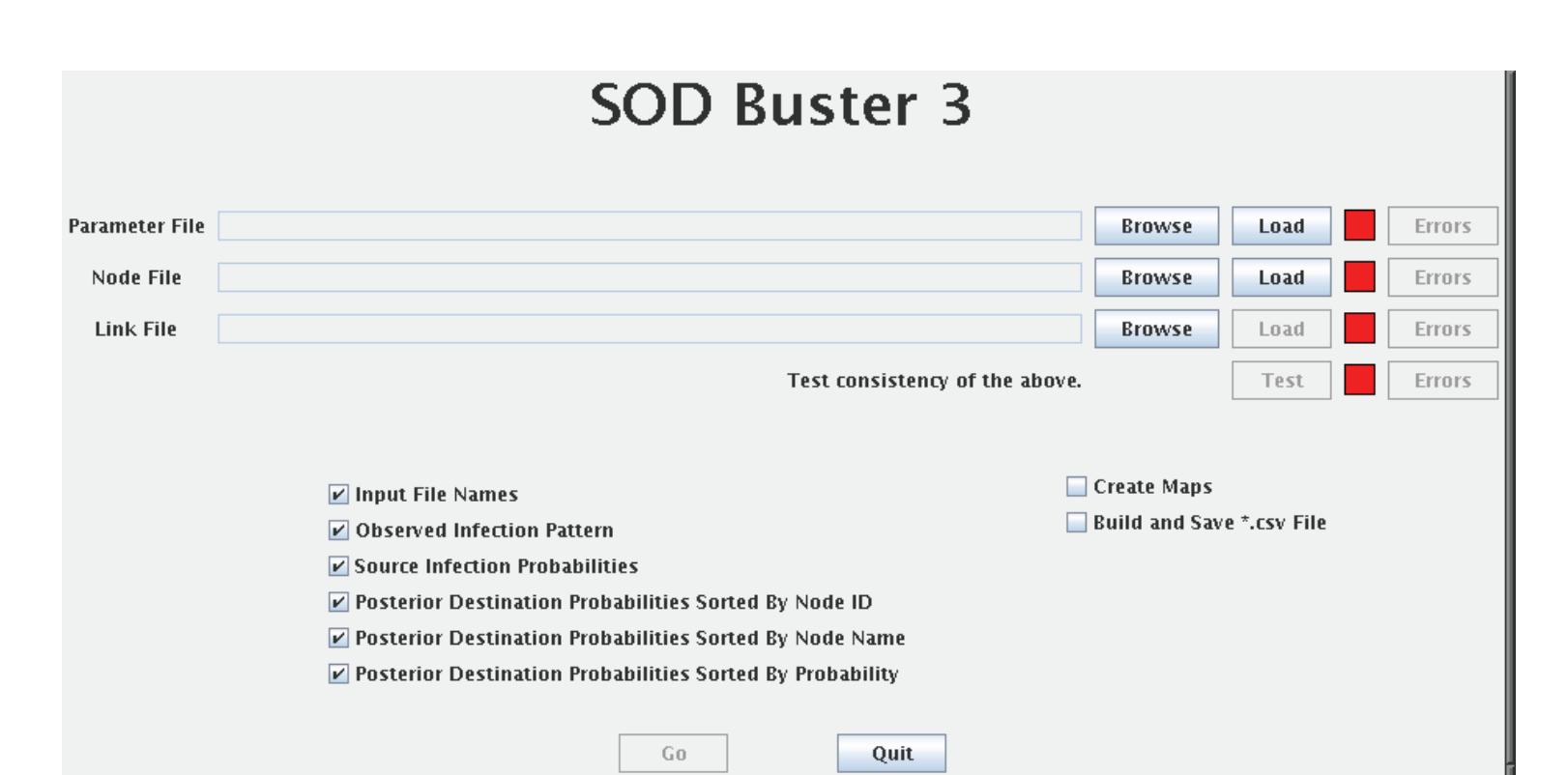
After the probabilities of exporting infectious materials have been updated attention moves to the unsurveyed recipients of nursery stock. For each unsurveyed recipient of nursery stock, these are called *destinations* in what follows, a probability is computed that this site has become recently infected. This probability is based on two characteristics of the destination, from which sources the destination's nursery stock is sent and how much nursery stock comes from each source. If a given destination receives a significant amount of its stock from high risk sources, that destination will be assigned a relatively high probability of infection. Conversely, if a destination receives very little stock from high risk sources, it will be assigned a low risk of infection.

Once risks have been assigned to the unsurveyed destinations, inspection resources can be mobilized to high risk destinations with the aim of identifying those sites that are, in fact, infected and taking actions to eliminate the threat of introducing *P. ramorum* into forests currently free of the pathogen.

SODBuster Opening Window

2007 West-to-East Nursery Stock Shipments

Sample of a Threat Map (Model Test)



Sample (Test) Program Output

Parameter File Name: july30.sdp
Node Information File Name: july30.sni
Link Information File Name: july30.sfl

Newly discovered infected site node IDs:

6 FL Jacks
8 MN Minne

Known clean site node IDs:

5 AL Birmi
9 NY New Y

Source Infection Probabilities

| Node ID | Node Name | A priori | Posterior |
|---------|-----------|----------|-----------|
| 1 | CA Los A | 0.1000 | 0.0817 |
| 2 | CA San D | 0.2000 | 0.9629 |
| 3 | CA Sacra | 0.3000 | 0.4952 |
| 4 | CA San J | 0.4000 | 0.6346 |

--Destination Nodes Sorted by node ID--

| ID | Node Name | P(Infected) |
|----|-----------|-------------|
| 5* | AL Birmi | 0.0000 |
| 6* | FL Jacks | 1.0000 |
| 7 | FL Miami | 0.3738 |
| 8* | MN Minne | 1.0000 |
| 9* | NY New Y | 0.0000 |

--Destination Nodes Sorted by node names--

| ID | Node Name | P(Infected) |
|----|-----------|-------------|
| 5* | AL Birmi | 0.0000 |
| 6* | FL Jacks | 1.0000 |
| 7 | FL Miami | 0.3738 |
| 8* | MN Minne | 1.0000 |
| 9* | NY New Y | 0.0000 |

--Destination Nodes Sorted by probability of infection--

| ID | Node Name | P(Infected) |
|----|-----------|-------------|
| 8* | MN Minne | 1.0000 |
| 6* | FL Jacks | 1.0000 |
| 7 | FL Miami | 0.3738 |
| 9* | NY New Y | 0.0000 |
| 5* | AL Birmi | 0.0000 |