Geographic information systems modeling for a forest insect: Case study for Pandora moth in the Western United States.

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INTRODUCTION

Pandora moth (*Coloradia pandora* Blake) inhabits parts of the western United States mostly defoliating ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.) trees. It also feeds on Jeffrey pine (*Pinus jeffreyi* Grev and Balf.) and lodgepole pine (*Pinus contorta* Dougl. ex. Loud.). Pandora moth outbreaks have been limited to only the western United States and within that region limited to soils of weathered granite or pumice (Speer et al. 2001). The literature suggests that the moth does not tolerate extreme cold either. We have used these limiting characteristics to develop a susceptibility map for pandora moth outbreaks.

A 622-year pandora moth outbreak chronology was constructed for south-central Oregon (Speer et al. 2001). Outbreaks in western United States have been reconstructed by a few researchers (Pohl et al. 2002, Swetnam pers. comm., Wickman et al. 1996, Speer et al. 2001), but most work has focused on recent outbreaks (Miller and Wagner 1984, Schmid and Bennett 1988). To fully understand this species and its

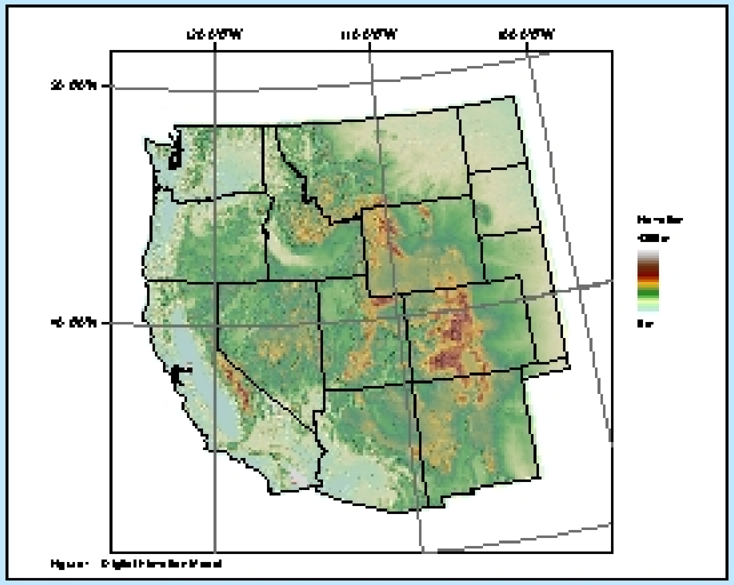

Figure 1. Digital Elevation Model

outbreak characteristics, more sites need to be studied throughout its habitat range and over long periods of time. In order to conduct such a broad-scale study, a map of potential outbreak areas is needed. We have used Geographic Information Systems (GIS) to locate areas of past and future outbreak areas incorporating soil type, vegetation type, and elevation. The model of pandora moth habitat will be used as a guide to sampling sites and for management in potential outbreak areas. Future work will continue to test and refine this susceptibility model.

METHODS

Data Types

Four data types are used in performing our GIS analysis. The first data type is associated with forest cover and was compiled jointly by the U.S. Geological Survey (USGS) and the United States Department of Agriculture (USDA) Forest Service in 2002. This data set portrays 25 classes of forest cover for the entire United States and was derived from Advanced Very High Resolution Radiometer (AVHRR) composite images recorded in 1991. The second data type is the world soils sub-order raster data, which is derived from the FAO-UNESCO soil map of the world combined with a soil climate map. The Environmental Systems Research Institute (ESRI) performed digitizing. The digitized vector data was then converted to raster format on a 2-minute grid cell and the final image was converted into a geotiff file referenced to a geographic coordinates system. The spatial resolution of this final image is approximately 1 km. The third data type used in this analysis is a compilation of Digital Elevation Model (DEM) derived from 1:250,000 USGS topographic quadrangles. DEMs are made of grid cells that contain elevation values and are freely distributed by the USGS. These files have a spatial resolution of 31 m (or 3 arc second).

Data Processing

The integration of data from different sources, different file structures, and different scales is a major challenge while performing a GIS analysis. We addressed this challenge by transformation and conversion methods that led us to 1) mosaic the DEM files into a single elevation file and derive slope information, 2) re-project all data to a unique projection system (Albers Equal Area), 3) convert all data into grid format and resample them to the same grid size, and 4) extract the extent of the study area from each grid file by clipping it with a vector file corresponding to the boundary of the area we are investigating. These steps allow us to perform pixel level analysis on each individual file as well as on all of them at once.

Data Analysis

Data analysis started with the selection and extraction of pixels with ponderosa pine and lodgepole pine forests from the 'forest types' data layer (Figure 3). This step constitutes the basis of our analysis since these two forest types are more suitable for hosting pandora moth species. Previous study of recent and past outbreaks in Oregon has identified orthents, cambids, cryepts, and xerepts as favorable soils type for pupation (Figure 4) (Speer and Jensen 2003, Speer et al. 2001). These four types of soils were extracted from our soils data layer and intersected with the identified pine areas. The pixels resulting from this intersection were considered as areas of high outbreak potential. Further intersection done with the elevation and slope layers allowed us to obtain an insight in to the slope and altitude of pandora moth habitat. The final map showing areas of high risk of outbreaks was compared to the Carolin and Knopf (1968) map and to the compiled USGS map of county-based documented pandora moth outbreaks in the Western United States.

RESULTS

We calculated 2,525,550 hectares of lodgepole pine or 42% of the total area and 3,464,526 hectares of ponderosa pine or 58% of the total area occupying our hazard area (5,990,076 hectares). We calculated 3% of cambids, 88% cryepts, 4% xerepts, and 2.7% orthents. The average slope for the total hazard area is 10.5 degrees. The minimum and maximum slopes are 0.12 and 72.7 degrees respectively. The average elevation for the total hazard area is 1661 m. The elevation of the suitable area varies from 37 m to 3321 m. The table below summarizes our results.

Soils	Avg slope	% of suitable area
Cambids	[illegible]	3
Cryepts	[illegible]	88
Xerepts	[illegible]	4
Orthents	[illegible]	[illegible]

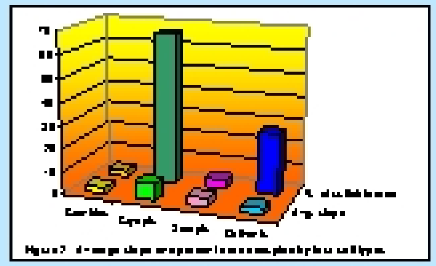

Figure 2. Average slope and percent area occupied by the soil types.

DISCUSSION

We located six million hectares (23,123 square miles) of pandora moth hazard. Our results present some differences compared to the Carolin and Knopf's (1968) map. This is mainly due to using only Oregon soil types (cambids, cryepts, xerepts, and orthents) and two tree species ponderosa pine (Pinus ponderosa) and lodgepole pine (Pinus contorta). One major difference was that of California. Carolin and Knopf located a sizeable hazard along the Sierra Nevada range. The soil types associated with ponderosa lodgepole pines growing on the mountain range are xeralfs, xerults, argids, and cryids. These soils were not incorporated into our analysis. The USGS internal map was compiled by county rather than state. This has some advantages for detail, but can also overestimate the outbreak area by including the whole county rather than specific areas within the county.

We located pandora moth hazard in northern Idaho, Montana, and Washington. Washington's climate is too harsh due to the ocean. Idaho and Montana have cold weather, which is a limitation to the moth's life cycle. With the addition of climate data, we can eliminate those northern hazard areas.

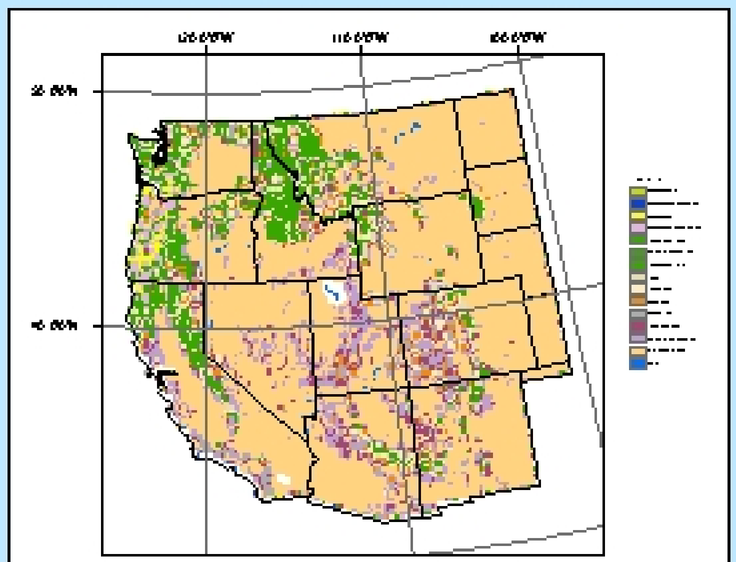

Figure 3. Forest Type Distribution

CONCLUSION

In conclusion, we used geographic information systems to model pandora moth hazard based on Speer and Jensen (2003) Oregon soil types. We also used USGS DEM data to calculate the slope and elevation of the potential hazard area, and a vegetation layer for determining the spatial distribution of pandora moth host trees. In addition, we included slope and elevation for more precise analysis.

Further work will include averaged climate data, detailed soils layer, aspect, and an additional tree species Jeffrey pine (Pinus jeffreyi) (Speer et. al. 2001). By including the aforementioned data to the analysis, we can expect a more detailed and precise model of pandora moth hazard in the western United States. Our research could be used by researchers, government agencies, and for states for management of natural areas to help prevent or lessen future outbreaks of pandora moth.

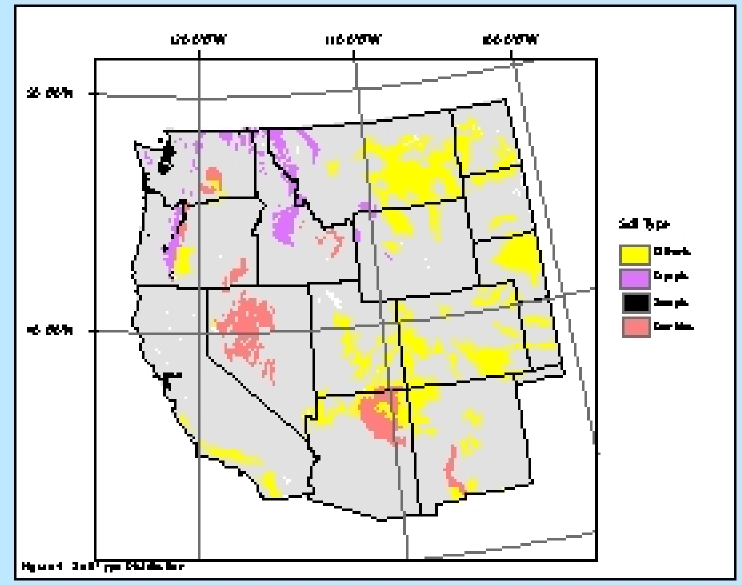

Figure 4. Soil Type Distribution

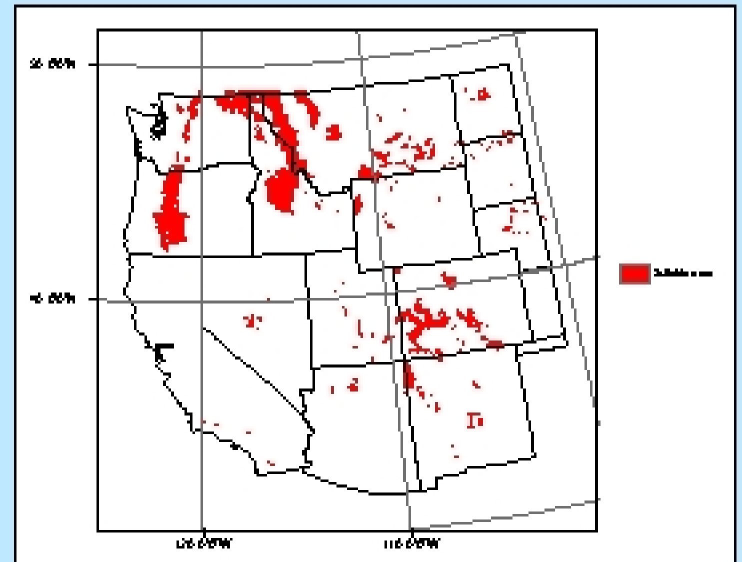

Figure 5. Pandora Outbreak Area

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Confirmed records of pandora moth outbreak in the western united states. http://www.npwrc.usgs.gov/resource/distr/lepid/moths/usa/271.htm

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