Are Hotspots of Biotic Disturbances Increasing in Western U.S. Forests (1997-2016)?

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Introduction

A warming climate is rapidly altering forest ecosystems and accelerating rates of tree mortality worldwide, and recent trends in multi-species tree mortality across North America have gained the attention of scientists and land managers.

Although forest disturbances are natural processes of dynamic ecosystems, unprecedented outbreaks of biotic disturbances such as pathogens and insects have contributed to the largest percentage of tree mortality in the U.S. (van Lierop et al. 2015), affecting more than 340,000 square kilometers of Western U.S. forests in the span of two decades.

While much research has focused on dynamics of single biotic disturbances (e.g. bark beetles, defoliators, pathogens), less is known about the spatial patterns and temporal trends of interacting biotic disturbances of forests in the United States.

The goal of this study: is to analyze the spatial and temporal patterns of biotic disturbances across western U.S. forests and the occurrence of two or more spatially and temporally intersecting biotic disturbances (hereafter referred to as 'Hotspots') using Geographic information systems (GIS) and the United States Forest Service (USFS) Aerial detection survey (ADS) data from 1997-2016 to answer the following questions:

1. **Are 'Hotspots' of insect outbreaks increasing in recent decades?**
2. **What is the spatial distribution of hotspots across western U.S. forests?**

Methods

The study area includes all forested areas in the United States west of North Dakota and Texas of which contains 11 western states. Within our study area, we focus on the spatiotemporal patterns of 27 distinct biotic disturbances of which we include 20 bark beetle species, 4 defoliator species, and 3 complexes of 3 tree species. Our study area is limited to the land encompassed by USFS regions 1, 2, 3, 4, 5, & 6 of which Insect and Disease Survey (IDS) data were acquired for spatial analyses from years 1997-2016.

Data Processing and Analysis

- ADS vector data is converted to 30 x 30 meter pixel raster data
- Querying of each disturbance causing agent (DCA) for every year from 1997-2016
- Python scripts used to :
  - Project all rasters
  - Reclassify presence of DCA
  - Aggregate layers to 510 x 510 meter pixels
  - Assign presence of disturbance if at least 10% of pixel contains disturbance

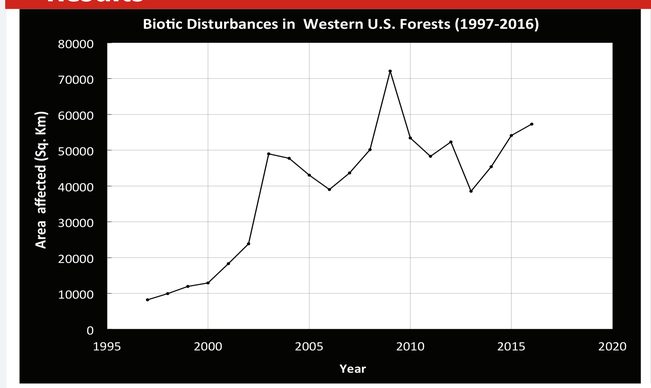
Hotspots are defined in 2 ways:

1. Annually: Sum of every DCA per year in order to identify temporal trends in the area s affected by two or more biotic disturbances in the same year.

2. Cumulatively: Sum by DCA then given assignment of 1 if any presence of distinct disturbance from 1997-2016, then summed again to produce cumulative hotspot map.

Figure 1: (Left) An undisturbed forest that is unaffected by recent biotic disturbances. **(Center)** A Forest stand that has experienced one biotic disturbance where some trees are killed while others compensate through the release of resources and remain healthy and unaffected by disturbance. (**Right**) A forest stand affected by more than one biotic disturbance causing severe tree mortality to multiple canopy species, with little to no ecological compensation.

Results



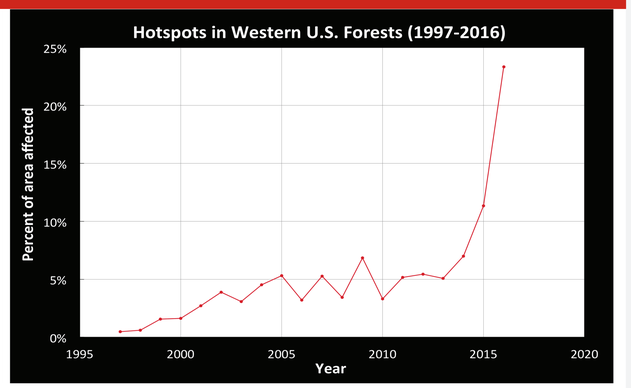


Figure 2: Annual comparisons of area affected by biotic disturbances over time demonstrating temporal trends (**Left**) Disturbance trend depicting total forested area affected by at least one biotic disturbance from 1997-2016 (**Right**) Disturbance trend of total forested area affected by 2 or more biotic disturbance in the same year - Hotspot from 1997-2016.

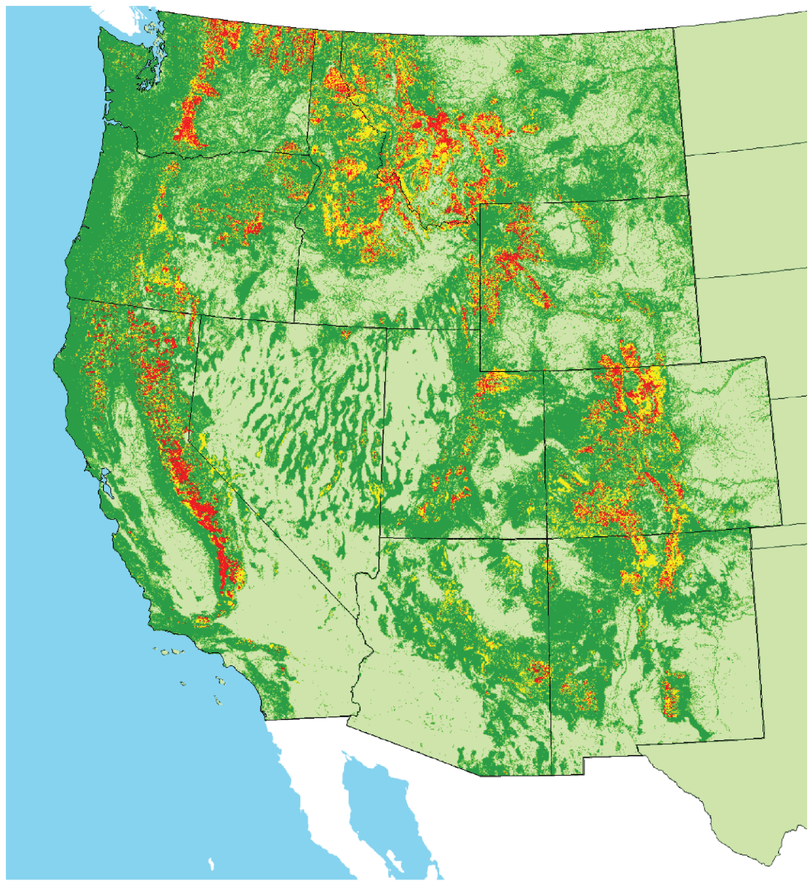


Figure 3: Hotspot analysis, depicting an ordinal scale of spatiotemporally overlapping biotic disturbances from cold spots to severe hotspots where 0 is unaffected forests, 1 depicts a single biotic disturbance, and 2 or more spatiotemporally intersecting biotic disturbances.

Hot Spots

0 1 >2

Discussion

- Biotic disturbances have been increasing over the past 2 decades with an exponential increase in the proportion of area affected by hotspots in a single year, with 25 % of all affected forests experiencing hotspots in 2016
- 30% of affected forested area in the western U.S. is experiencing hotspots, or more than 100,000 square kilometers of forests.
- In general, coldspots (areas with little to no BD activity) occur in two general types of locations:

  1.) Areas along the Pacific Coast, where host tree density and available moisture are both high.
  2.) Drier and low-elevation locations inland where host tree density and available mois ture is low.

- Hotspots occur where host tree denisty is high and in middle to high elevations along mountains (The Cascade, the Rocky Mountain, and Sierra Nevada ranges), but moisture is moderate, and may be experiencing greater drought stress as temperature increase

Conclusions

Our results suggest an increase in the occurrence of hotspots, which may be an indication of a lowered ability for ecological compensation in affected forests across the western U.S. and therefore hinder overall forest resilience to biotic disturbances.

The identification of hotspots across western U.S forests aids further investigations of the mechanisms that drive overlapping biotic disturbances and how a warming and drying climate may affect them.

Future work will be valuable in quantifying intensity of hotspots through remote sensing and ground validations.

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