United States Forest Disturbance Trends Observed Using Landsat Time Series

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Objectives:

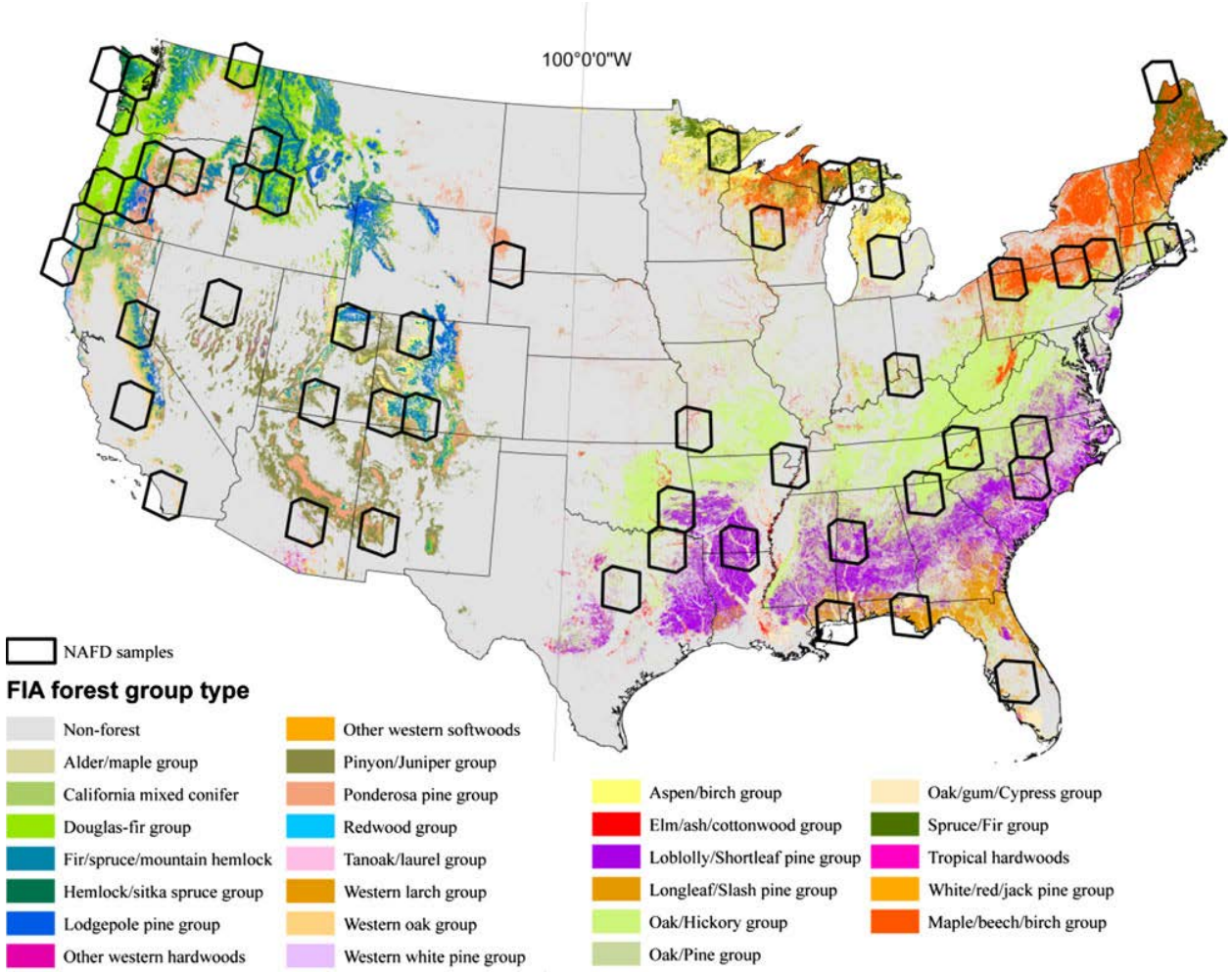
- This study was designed to fill the gap that exists between current forest monitoring methods and the important need to assess and monitor forest disturbance, which strongly affects the composition, structure and function of ecosystems.
- The North American Forest Dynamics project (NAFD) has examined a geographic sample of Landsat satellite image time series at a relatively high-temporal frequency (approximately annual time step) to assess trends in forest disturbance across the conterminous US for 1985-2005.
- The sampling approach selected consisted of 50 scenes and for each of these a time series of cloud-minimized, seasonally consistent imagery was assembled.
- The geographic sample design used a probability-based scheme to encompass major forest types and maximize geographic dispersion.
- The time series of each pixel in a given image stack was analyzed using the Vegetation Change Tracker (VCT) algorithm to detect disturbances.
- Forest disturbance was defined as any event that caused either substantial mortality or leaf area reduction within a forest stand.

New Science:

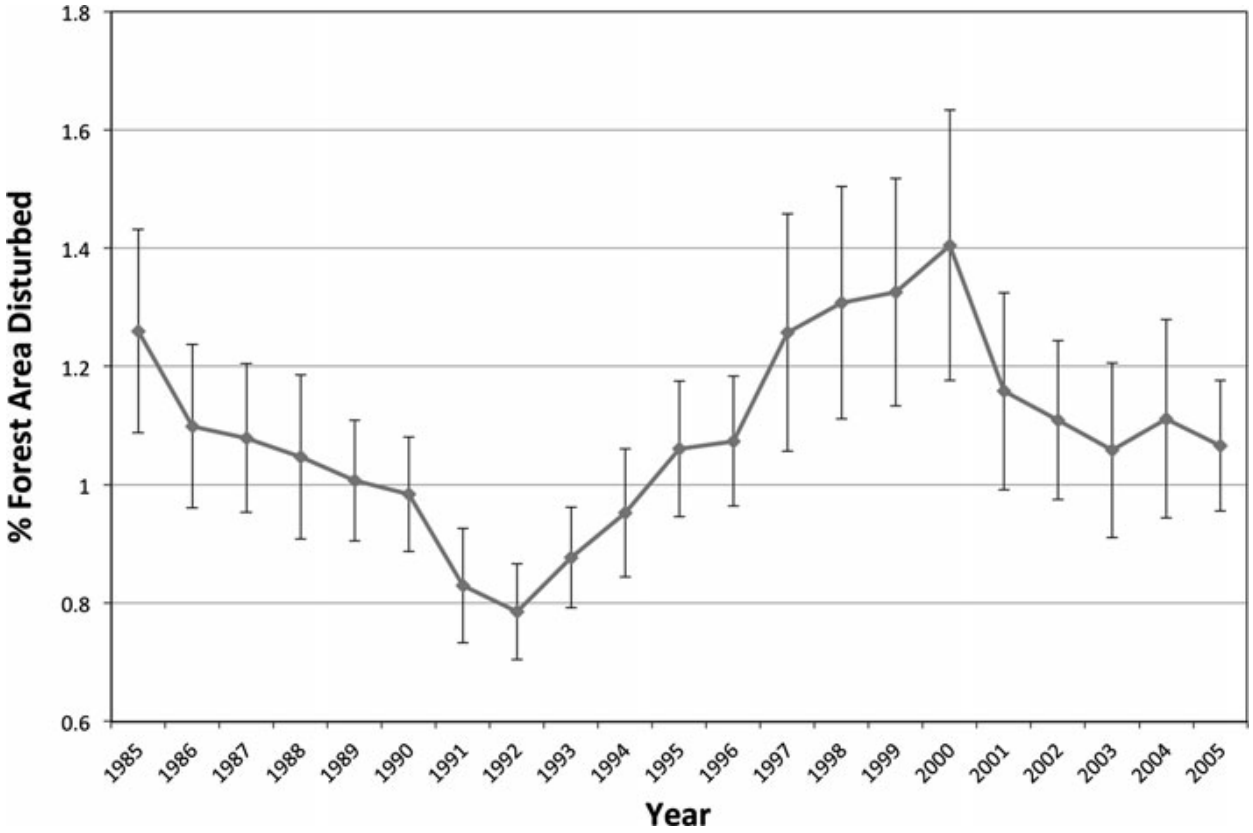
- The analysis indicates that, on average, 2.77 Mha y^{-1} of forests were disturbed annually, representing 1.09% of US forestland.
- However, disturbance rates calculated from VCT map products were biased, underestimating total disturbance by an average of 24% across all validation sites.
- Adjusting NAFD results for this underestimation bias would increase the national disturbance rate to 3.63 Mha y^{-1}.
- Raw, per-scene forest area and disturbance rates for each of the 50 samples showed significant geographic variability.
- Western US disturbance rates were associated with active fire years and insect activity; they also appear to have increased substantially beginning in the late 1990s.
- Higher disturbance rates in the eastern US, especially the southeastern US, are more strongly related to harvest rates in the managed forests and more closely track variability in economic activity (GDP).
- The VCT approach used with a biennial time step has limited sensitivity to low-intensity disturbances, but effectively captures most rapid stand-clearing and non-stand clearing events.
- Results also suggest that forest disturbance rate can change rapidly across large regions.
- The results presented here represent the first satellite-based estimates of yearly forest disturbance for the conterminous United States.

Significance:

- Existing US land management inventories were not designed to monitor forest disturbance.
- Both climate change and the increasing global demand for wood and fiber products are likely to drive increases in forest disturbance rates.
- Significant changes in forest disturbance rates will alter water and carbon cycles in forest stands, as well as impact the habitat and biodiversity of these ecosystems.
- To effectively understand how forest disturbance impacts forest state and functioning, disturbance rates need to be quantified at the spatial grain where human management and natural disturbances occur, as well as a time step and spatial scale relevant to the affected processes, and the temporal period must be relevant to establishing baselines meaningful to forest policy initiatives.
- In the US, the lack of consistent, high temporal resolution estimates of forest disturbance remains an important gap in the efforts to model and manage forest carbon at a national scale.
- Future satellite-based studies of disturbance at regional and national scales should focus on wall-to-wall analyses with annual time step for improved accuracy.
- Based on the analysis of data in this study, as well as the advent of free Landsat data distribution and increased computing power, the NAFD project is moving forward toward wall-to-wall, annual mapping in the development of a powerful system for spatially explicit monitoring of forest cover in the conterminous US.



NAFD sample scenes (unique, non-overlapping scene areas) overlaid on US forest type map (Ruefenacht and others 2008).



NAFD national disturbance rates obtained by combining results for the eastern and western strata, calculated by year (percent of conterminous forest area disturbed per year). *Error bars* Sampling error ($\pm 1\,\sigma$).