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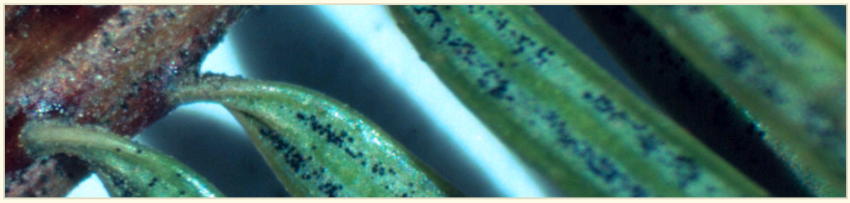

Forest Tree Diseases and Climate Change

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Synthesis

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Previous (2008) versions of this paper are **available here**.

Introduction:

Tree diseases occur everywhere that forest trees grow. Infectious diseases caused by biotic pathogens develop over time from interaction of these pathogens with a favorable environment and susceptible host plants [1]. Environmental factors that cause plant stress, especially from moisture deficit caused by drought, commonly predispose trees to forest pathogen attack. Some diseases are species-specific, while others affect multiple host species. Pathogens that incite tree diseases include fungi, bacteria, viruses, parasitic plants, nematodes and other microorganisms. Insects can play a major role in disease development by serving as vectors, providing wounds that allow pathogen ingress, and other functions [2]. Non-infectious forest diseases are caused by abiotic factors that are directly damaging to tree health, such as freezing temperatures and air pollutants [3].

Anticipated changes in climatic conditions may impact the prevalence and severity of these non-infectious diseases. With respect to infectious diseases, altered climatic conditions may dramatically affect the outcome of pathogen – host – insect interactions in forest environments. The cascade of multiple changes will influence a forest's ability to sustain goods and services at existing levels [4,5]. Direct damage to host tissues occurs in affected trees and can lead to tree mortality.

Understanding the relationship between climate and tree disease is essential for addressing issues associated with changing climate [6] at different spatial scales. Several relationships where greater understanding is required are:

- Effects of biotic and abiotic disease factors on tree survival and growth, forest structure, and species composition [6].
- Effects of pathogenic and decay fungi on the forest carbon cycle which impact forest carbon stocks and fluxes [7].
- Development and impact of tree pathogen and associated insect - host interactions under varying temperature and precipitation regimes.
- Documentation of beneficial changes due to changing climate effects on tree diseases and tree susceptibility in relation to forest species diversity and forest structure [6].

Introduced invasive pathogens, such as the chestnut blight fungus and white pine blister rust, caused extensive damage to U.S. forests in the past century [8]. Thus, studies of both native and exotic invasive pathogens are needed. Understanding how the severity and distribution of tree diseases are affected by seasonal changes in temperature, moisture conditions (precipitation, relative humidity, and soil water availability), tree phenology, and tree physiological stress is also important in forecasting the direction of change expected under predicted climate scenarios.

Likely Changes:

The effects of climate change on forest tree diseases will vary by spatial scale, and will depend on the trajectory of change. Projections and prediction maps of where drier and wetter conditions will likely occur in the U.S. have been and will continue to be published [9].

Predictions of changes in impact caused by forest diseases have been made under both "warmer and wetter" and "warmer and drier" scenarios. For diseases where temperature and moisture more directly affect host susceptibility to infection and disease development, "warmer and drier" climate will favor disease increase. In general, root and canker diseases fall within this category. As a specific example, Armillaria root disease in the western states is predicted to increase in severity and impact under this climate scenario [10]. Climate warming accompanied by increasing drought events (warmer/drier) also can lead to increases in "decline disease" frequency and severity [11]. Such diseases typically involve sequential and additive effects of site conditions, drought, and insect and pathogen build-up on stressed hosts [12]. With warming temperatures, some forest tree diseases may be able to occur further north and/or at higher elevations. Opportunistic pathogens may also be favored by such changes.

Armillaria root disease mushroom fruiting body and tree mortality in an Idaho forest. Under a 'warmer and drier' climate scenario, this disease is projected to increase in severity and impact. Photo credit: Mee-Sook Kim, U.S. Forest Service.

Root Disease | Infected Douglas-fir | Infected Needles | Blister Rust | Dead Tanoaks

Diseases where temperature and moisture directly affect the causal organism's reproduction, spread, infection and survival are predicted to increase under warmer/wetter conditions. In general, foliar and rust diseases fall within this category. Predictions based on warmer/wetter

projections have been made for specific diseases such as sudden oak death, Phytophthora root rot and Swiss needle cast [10].

Seasonal shifts in precipitation pattern alone can lead to increasingly severe occurrences of tree diseases. For example, documented climate changes over one or more decades that affected timing of rainfall were associated with severe outbreaks of red band needle blight on lodgepole pine in British Columbia [13] and bur oak blight in Iowa [14].

The complexities of climatic effects on community interactions in which diseases occur make it extremely difficult to assign probabilities or predict the trends of climate change impact on forest tree diseases in the future [15]. Changes in precipitation timing, intensity and form within a region or state will vary, further contributing to the complexity of disease prediction. Even microclimate differences can profoundly affect disease severity. However, some general principles can be helpful in predicting responses of forest tree diseases to changing climatic conditions:

- Prediction of disease outbreaks will be more difficult in periods of rapidly changing climate and unstable weather, because altered reproduction and spread of forest tree pathogens will influence changes in initiation, development and severity of diseases.
- Host resistance to pathogens may be overcome as trees become stressed or as pathogens' evolution accelerates more quickly than their long-lived hosts.
- Warmer winters will contribute to greater overwintering success of pathogens and/or associated insects, leading to increasing disease occurrence and severity.

The rate and pattern of wood decay in forests changes due to influence of changing moisture and temperature regimes on decay fungi. Thus, carbon cyling rates may increase or decrease depending on the direction of future climate changes.

Options for Management:

Forest managers, whether working at the local or the landscape scale, should be aware of current and historic forest health conditions in their jurisdictions, and then integrate that knowledge with climate change projections. Monitoring, forecasting, planning and mitigation strategies are needed to prevent and to adaptively manage tree diseases at various geographic scales [16].

Monitoring – Early detection of tree diseases can increase the potential for successful disease management. Thus, continued and improved surveillance of forests for tree health problems is required. Integrated data from state, federal (such as the USFS Forest Inventory and Analysis program and the USFS Forest Health Protection programs), and private monitoring are useful for detecting deviations from historical baseline conditions. Follow-up investigations of identified problems and "at-risk" forests are also required.

Forecasting - Climate change scenarios have been used to estimate future risks for several tree diseases [17, 18, 19]. However, uncertainties generated by forecasting must be sufficiently characterized and additional species need to be addressed. Forecasting may be achieved using models, risk analysis and risk rating systems. **Models** may 1) project potential forest disease impacts, 2) provide insights on the magnitude and direction of change, 3) help focus monitoring activities, and 4) aid in the evaluation of management strategies [20]. **Risk analysis and risk rating systems** are developed through evaluation of available evidence and anticipated behavior of a plant pathogen to estimate its impact in a new environment and to determine a management response.

Planning and Mitigation Strategies – Increasing the capacity of an ecosystem to absorb disturbance without shifting to a qualitatively different state (ecological resilience) is required to mitigate effects of climate change [21], using proactive options such as

- Increasing species and age class diversity to promote growth and resilience to mortality,
- Using appropriate silvicultural interventions to increase tree vigor and lower pathogen and insect pest impacts under predicted climate scenarios,
- Carefully and judiciously using facilitated tree species migration, and
- Increasing tolerance and resistance to pathogens as part of breeding programs designed to increase species tolerance to environmental stressors.

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