Sudden Oak Death in the Context of Global Tree Mortality and Regional Efforts to Limit Carbon Emissions

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An emerging body of published research, ongoing field and modeling studies, and disease management experiments are building an understanding of *Phytophthora ramorum* impacts to carbon cycling from stand-to-landscape scales. California has been recognized as a leader in policy and management efforts to limit greenhouse gas emissions. The large economy, annual greenhouse gas emissions, and the nexus of natural resource, economic, and infrastructure challenges are realistic reflections of the complexity and difficulty of enacting change at global scales. Sudden oak death is the most significant source of tree mortality in the coast and Klamath ranges of the state. The scale and severity of mortality associated with the disease is comparable to other large tree mortality events globally; thus, the disease and the collective management response also holds implications for regional, national, or global carbon emissions (Cobb et al. 2017a).

Using a large plot monitoring network and current estimates of host distribution and density, sudden oak death impacts were recently estimated to exceed 50 million killed tanoak and oak trees in California and Oregon as of 2012, likely resulting in emissions exceeding 2.5 Tg of carbon between 1995 and 2012 (Cobb et al. 2019), or about 0.6% and 7.6% of the state total emissions and combined agriculture/forestry emissions in 2016, respectively (Air Resources Board 2018). Although the total trees impacted by the disease is lower than that of the Sierra Nevada bark beetle outbreak (with about 138 million dead trees), the chronic and expanding dynamics of the disease suggest the total could become the greatest biotically-driven emissions in the state. Within disease impacted stands established pathogen populations suppress live carbon biomass accumulation while also increasing emissions from decomposition (Cobb et al. 2013, Cobb and Rizzo 2016). Disease impacts to fuels can lead to heightened carbon release from soils during wildfire, an ecosystem carbon pool that is otherwise often protected from aboveground disturbances (Cobb et al. 2016).

Despite the large scale and amounts of carbon lost due to the disease, a body of stand-scale experiments and recent modeling studies leveraging data on patterns of partial resistance in tanoak suggest a suite of management interventions can be effective in limiting or ameliorating these releases. Mastication and hand-pile treatments have been demonstrated to increase potential for regeneration of less-susceptible species, reduction of ground fuels, and to possibly slow invasion of uninvaded stands (Cobb et al. 2017b). These treatments initially increase soil carbon release from decomposition and may depress atmospheric methane (CH_4) consumption associated with increased soil moisture. It is unclear whether carbon accumulation in live trees, either due to increased growth of remaining canopy trees, or by recruitment of less-susceptible species, will exceed this release rate within a decade of treatment although growth and yield estimates suggest this will eventually occur. Carbon sequestration in uninvaded stands could be further increased and standing pools protected by utilizing patterns of partial resistance in tanoak, which recent work has shown to be present frequently among stands but always at low densities with a random distribution within stands (Cobb et al. 2018). From the perspective of the state's greenhouse gas goals, the extent and severity of sudden oak death's impacts to forests must not be ignored or discounted. Stand scale management is increasingly showing that responses can be effective and a vision – as well as clear plan – for scaling up treatments at the scale of the disease is now needed.

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