Forests (Oaks) in North America

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Background information

In North America, oaks (*Quercus,* Fagaceae*)* are the most abundant and diverse woody plants and one of the most highly valued, important forest trees as measured by provision of ecosystem services and economic value. Oaks dominate ecosystems throughout much of North America from Pacific Coast evergreen forests, to Eastern temperate deciduous forests, and southwestern oak-piñon-juniper woodlands (Johnson et al 2019). Many oak species are majestic, overstory trees but others are shrubs or small trees, particularly in drier habitats (e.g., chaparral), and higher elevation forests. Oaks grow in well-developed soils but also thrive in serpentine soils, sandy barrens, and swamps (Nixon 2006).

Oaks provide numerous ecosystem services that support human well-being: provisioning shelter, regulating the environment, and enhancing culture and aesthetics. Oaks are economically important as sources of high-quality lumber (Burns and Honkala 1990). Ecologically, oaks provide forage, nesting and other habitat for birds, mammals, and fungi. They are foundational species that control wildlife populations and community dynamics, as well as modulate ecosystem processes (e.g., carbon balance and water supply) (Cavender-Bares 2016; Ellison et al 2005).

Oaks were designated by the U.S. Congress as America's national tree in 2004 and are a symbol of strength and longevity (International Oak Society 2001). The cultural and aesthetic values of oaks include stately shade trees along boulevards and in recreation areas and spectacular foliage color in fall. For indigenous peoples, acorns are an important food source and oak fibers are used in basketry, regalia, and structures (Anderson 2007).

Ecosystem Services: North American oak forests provide many benefits: 1. **Provisioning Services**: food, fiber, materials; 2. **Regulating Services**: climate, soils, water and 3. **Cultural Services**: culture, spiritual, beauty.

PlantSystem considered in this report

The Plant System assessed in this section is primarily the genus *Quercus* (oaks, Fagaceae). Taxonomically, within North American *Quercus* three groups are recognized, the white oaks (section Quercus, also called section Leucobalanus or Lepidobalanus), the red or black oaks (section Lobatae or Erythrobalanus), and the intermediate or golden oaks (section Protobalanus) (Nixon 2006).

In North America, oaks are widely distributed, found across the East through to the West Coast with species richness highest in the southern U.S. Oaks are abundant, with an estimated 43 billion stems in the U.S., representing 11 percent of the total U.S. tree population. White oak, *Quercus* *alba*, is most common representing 19 percent of all oak biomass (Oswalt 2019). Also, prominent and valued as a select wood producer is northern red oak, *Q. rubra,* the tallest and most rapidly growing eastern oak. The native ranges of white oak (*Q. alba*) and northern red oak (*Q. rubra*) extend from the mid-west and eastern U.S. states into southeastern Canada (Burns and Honkala 1990).

In the western U.S., coast live oak, *Q. agrifolia,* dominates Pacific evergreen forests where it is an important host of the invasive pathogen, *Phytophthora ramorum*, cause of sudden oak death. In the California landscape, this tree species is prized for its broad spreading canopy, which is often wider than the tree's height. Tanoak, *Notholithocarpus densiflorus* (Fagaceae)*,* another common host to *P. ramorum,* is considered an evolutionary link between oaks and chestnuts.

Historically, the major disease problems of *Quercus* species in eastern states and Texas are oak wilt and oak decline (Billings 2000). Numerous oak species are naturally infected by the oak wilt pathogen, *Bretziella fagacearum*. In general, members of the red oak group are highly susceptible to oak wilt compared to species of the white oak group that are moderate to high in disease tolerance (Juzwik et al 2011). Multiple species of both red and white oak groups are significantly affected by oak decline but differ by the suite of biotic agents responsible. Multiple occurrences of episodic decline and mortality of oaks, particularly red oak species, have been observed in northeastern, mid-Atlantic, Midwestern, and southern oak-hickory forests (Oak et al 2016).

Oak forests health in North America

State of oak forests health in the past 30 years

Over the past several decades, North American oaks, while still abundant, have become less dominant, particularly in the eastern U.S. (Fei et al 2011). Population declines vary geographically and by species. Despite the prevalence of oaks across the northern U.S., multiple studies indicate that oak sapling mortality and lack of regeneration present a doubtful future for oak forests (Woodall et al 2010).

Invasive pathogens are damaging oaks, and the continued introduction of new invasive pathogens poses a significant challenge to oak populations in the U.S. and Canada (Aukema et al 2010; Conrad et al 2020). Sudden oak death, caused by *Phytophthora ramorum*, was first recognized in the mid-1990s in coastal evergreen forests in the San Francisco Bay Area. The invasive pathogen was introduced on ornamental nursery stock, and despite quarantines and eradication efforts, has killed an estimated 50 million oak and tanoak (*Notholithocarpus densiflorus*) along the Pacific Coast in California and southern Oregon (Cobb et al 2020).

Oak wilt epidemics, caused by *Bretziella fagacearum* (formerly called *Ceratocystis fagacearum*), are on-going in Texas and north central states, resulting in the death of tens of thousands of oak trees each year (Billings 2000, Juzwik et al 2011).

Sudden oak death, caused by Phytophthora ramorum, on coast live oak (Quercus agrifolia) in coastal California – top view (photo courtesy of Susan Frankel)

Severe, multiple year *Tubakia iowenensis* foliar infections on bur oak (*Q. macrocarpa*) has led to crown dieback and tree mortality in Iowa and Minnesota (Harrington et al 2012). Change in severity of this disease has been attributed to increased spring precipitation resulting from climate change.

Oak decline and climate change were identified as critical current and future threats for oaks in the eastern U.S. (Conrad et al 2020) and are also a significant concern in the central and southern U.S. Accelerated oak mortality and progressive crown dieback of dominant and codominant oaks is common particularly for red oaks, in stands with lower site quality, older age classes (> 70 years), and relatively dry site conditions (i.e., shallow or excessively drained soils) (Oak et al 1996). Oak decline associated with drought, red oak borer and Armillaria root disease caused significant mortality of oaks in Missouri and Arkansas (approximately 2002 through 2012; Fan et al 2012).

Evolution of oak forests health over the recent 10 years

Over the past 10 years, invasive pathogens continue to kill trees and expand into new areas. For sudden oak death, *Phytophthora ramorum*, in 2015, a new aggressive strain damaging trees in Europe (EU1), was detected killing tanoak in Oregon near a nursery where the EU1 strain was first detected in 2012 (Grünwald et al 2019). The pathogen is under mandatory eradication but continues to expand its range (Navarro et al 2020). Oak mortality increases when wet springs are followed by hot, dry summers. In California, *P. ramorum* has killed, on average for 2018 and 2019, over a million trees per year along the Pacific Coast (COMTF 2020). The pathogen has become well-established throughout many coastal forests and continues to spread via windblown rain expanding the area of infestation and loss of oaks.

Sudden oak death on coast live oak in coastal California – dead standing tree (photo courtesy of Susan Frankel)

A significant expansion of the oak wilt disease range has occurred with new detections of *B. fagacearum* and red oak mortality in New York State since 2008 (Jensen-Tracy et al 2009; NY Cons 2020). Introduction of the pathogen to new geographic areas in the state is attributed to movement of diseased firewood and logs.

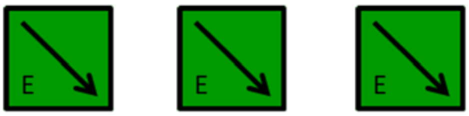
Conditions conducive to oak declines are increasing due to changing environmental conditions and anthropogenic influences that make hardwood forests vulnerable to disturbance. In response to changes in climate, novel decline etiologies, in particular high temperatures followed by secondary agents, appear more aggressive than in the past (Haavik et al 2015). Vegetation models indicate oaks in the southern-most part of their range may undergo extinctions in the future due to increases in temperature and drought (Rodríguez-

Sudden oak death on coast live oak in coastal California – dead grounded tree (photo courtesy of Susan Frankel)

Calcerrada et al 2017). Drought–pathogen (*Biscogniauxia)* interactions in the Ozarks, Missouri caused 10.0% mortality of white oak (*Quercus alba*) and 26.5% mortality of black oak (*Q. velutina*) in a single year, 2012-2013 (Wood et al 2018). Significant white oak (*Q. alba*) mortality associated with *Phytophthora* species has been reported in Ohio, Missouri, and Iowa (Nagle et al 2010; Reed et al 2019).

Ecosystem services, as affected by plant disease

Provisioning **Regulating** **Cultural**



Level of provisioning, regulating, and cultural ecosystem services generated by oak forests, as affected by plant disease, in the past 30 years

Commonly oaks are foundational species, dominating ecosystems and responsible for the services they provide for ecological function, wildlife habitat and human well-being. Oak forests contribute a wealth of provisioning, regulating and cultural services. Because of their longevity, threats to their health are of particular economic importance to commercial forest landowners, because long-term investment may be degraded and replacement of a damaged or destroyed forest takes multiple decades (Boyd et al 2013). Similarly, losses of ecological or cultural benefits due to pathogens can take a long time to return or may never be restored.

Provisioning services. In the U.S., oak species accounted for 41 percent of the eastern hardwood lumber production in 2010 and is used for wood flooring, household furniture, kitchen cabinets, and millwork (e.g., doors, windows, molding). Lower grade wood is used for pallets and railroad ties. Oak specialty products include whiskey and wine barrels, gun stocks, and guitar bodies (Luppold and Bumgardner 2016). As a food source for humans, acorns are important to indigenous peoples. Oak forests also support hunted or gathered food by providing habitat for wild game, berries, mushrooms, and honey (Miller and Lamb 1984).

Oaks support a vast array of wildlife including deer, birds, bats, amphibians, reptiles, and other animals. Mast is relied on for food. For nesting, animals utilize trunk cavities, coarse woody debris, and leafy canopies (McShea and Healy 2002).

Oak wilt has led to loss of habitat for the golden-cheeked warbler in Texas (Camilli et al 2009). Oak mortality in large disease foci may cover multiple hectares (Appel et al 1989) and leads to changes in stand structure. In addition, disease suppression programs to manage oak wilt in forest stands has led to cutting of numerous large areas (up to several hectares) of oak forests in states with epidemics (Bruhn and Heyd 1992; Lampereur and Walker 2018). In some situations, the subsequent regeneration in treated sites has led to a change in species composition, such as maple (*Acer* spp)-dominated stands.

Regulating services. Oak forests regulate numerous ecological processes including biomass production, carbon sequestration, biodiversity, pollination, decomposition, nutrient fluxes, and energy flow. They control water dynamics regulating flood control and water purification (Cavender-Bares 2019). Oak and hickory are of major importance in maintaining biodiversity (Fralish 2004). Loss of these species would have cascading effects on insect and bird populations, understory woody and herbaceous plants, as well as potential to cause increased soil erosion and loss of nutrients.

Cultural services. Oaks may live for hundreds of years. Majestic oaks in plazas, parks, and forests are symbols of longevity and strength. Oak trees are of enormous importance to humans who cherish particular oak landscapes, species, cityscapes, or individual trees (Boyd et al 2013).

Many North American societies and religions use representations of oaks in traditional rites and celebrations (Leroy et al 2020). Because of these associations, plant pathogen threats to oaks carry strong emotional meaning for many people.

Evolution of provisioning, regulating, and cultural ecosystem services generated by oak forests, as affected by plant disease, over the recent 10 years

As oak stands decline or experience accelerated mortality due to invasive species and climate change, many of the ecosystem services they provide decrease. New openings in stands may revegetate to shrubs, herbaceous plants or other tree species changing the landscape character and threatening numerous ecological processes. Oak mortality is of particular concern for the loss of mast which cascades through the ecological food web (McShea et al 2007).

Provisioning wood. According to Luppold (2019), since 1992, *Quercus* species have accounted for a third of the eastern hardwood growing stock volume, but oak poletimber [12.7 to 27.7 cm diameter at breast height (dbh)] volume has declined from 27 percent of total hardwood poletimber volume in 1992 to 23 percent in 2012 with most of this change occurring since 2002. This decline in poletimber volume of oak species is a precursor to reduced oak saw timber volume in the coming decades. For hardwood timber markets, other species may be suitable replacements, but the aesthetic attributes of oak wood are lost.

Complementary information

In this assessment we focused on the effects of pathogens and included climate as an abiotic disease when it disrupts plant health. In forests, pathogens interact with fire, insects, and other disturbance agents to influence tree survival, growth, stand composition and successional patterns. The extent of disease outbreaks is altered by other disturbances such as stand destroying fire, large-scale wind events, or large-scale insect outbreaks (e.g., spongy moth [*Lymantria dispar*]). Land use patterns, fire history and drought influence oak health and distribution (Abrams 1992). In California and many parts of North America, development including subdivisions, vineyards and other agricultural uses are causing oaks to disappear from landscapes (Gaman and Firman 2006).

Declines are increasing due to climate change, due to more frequent and intense periods of excessive heat and drought. While the effects on North American oaks varies depending on the local and regional environmental conditions, climate change is altering survival and growth (Haavik et al 2015).

Trees are long-lived organisms and tree populations may gradually shift their ranges over hundreds or thousands of years. Ecosystem composition fluctuates over eons, while humans tend to focus on observed changes in their local areas over a few years. Humans also tend to be most concerned over changes that directly affect them (i.e., lost timber revenue, a lack of shade canopy in their community) while loss of vital ecological ecosystem services (nutrient and hydrological cycling) may be less apparent and overlooked.

We are reasonably confident in this assessment. There are adequate studies to support this assessment, but North America is a large geographic area and forest conditions vary greatly from location to location. Some areas are exposed to invasive species, declining, or stressed due to climate change while other areas are thriving.

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