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Review

A review of southern pine decline in North America

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ABSTRACT

The southeastern United States is among the most productive forested areas in the world. Four endemic southern pine species – loblolly, longleaf, shortleaf, and slash – contribute significantly to the economic and ecological values in the region. A recently described phenomenon known as Southern Pine Decline (SPD) has been reported as having widespread impact in the southern pine region, particularly on loblolly pine. Root-feeding weevils and their associated fungi have been suggested as causal agents, even though literature and empirical research suggests that they are secondary insects colonizing weakened trees. Further, no published information exists about whether their associated fungi can cause mortality of mature trees in the southeastern U.S. Since there are significant management implications for pine health, we reviewed and critically examined the SPD phenomena on the southern landscape. Our regional analyses of USDA Forest Inventory and Analysis data show no discernable patterns related to pine growth or mortality, especially as related to topographic factors. There are no large-scale patterns related to pine mortality suggesting multiple interacting factors impacting tree health at stand-level. As such, the hypothesis that SPD is a regionally important decline syndrome and labeling declining southern pine stands as SPD is not supported. Instead, we discuss many abiotic (soil types, climate) and biotic (insects, pathogens, genetics) factors that may be interacting with each other and affecting southern pine health. Finally, we suggest management recommendations for landowners with pine health issues.

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1. Factors affecting tree health

Tree diseases are the result of complex interactions among multiple abiotic and biotic factors, and appear when the three components of the disease triangle occur together: (1) a pathogen; (2) a susceptible, present host; and (3) the appropriate environment for the pathogen (Stevens, 1960). As diseases do not appear instantly, Tainter and Baker (1996) added a fourth component – time. Disease etiology can be simple or complex, and the relative importance of the different components is not always apparent (Manion, 1981). In a simple disease model, the pathogen is the primary causal agent. For instance, oak wilt (*Ceratocystis fagacaerum* [Bretz] Hunt) may be considered a simple disease model – the pathogen is the primary tree-killing factor, provided it has access to a host (which generally occurs via being transmitted by nitidulid beetles into natural or human-caused wounds on the tree) and is in an environment conducive to infection (Sinclair and Lyon, 2005). Declines, on the other hand, often have complex etiologies (Manion, 1981) and can be considered complex disease models. Declines feature multiple, interchangeable abiotic and biotic components that interact with each other and have varying levels of importance to the overall health of the host (Houston, 1987). In these cases, the mere presence of the pathogen and access to a host in an appropriate environment does not always cause disease. Often, multiple additional stressors to the host are required prior to disease development (Schoeneweiss, 1975).

Sinclair (1966) defined three categories of factors affecting tree health: (1) predisposing factors such as soil type, climate, and tree genetics that influence trees over the long-term; (2) inciting factors such as defoliation and drought which have short-term influence on tree health; and (3) contributing factors such as opportunistic wood-boring beetles and fungi which further weaken and eventually kill the tree. These lead to a "decline and death spiral" – a progressive process of deterioration in tree health and vigor (primarily in mature trees) followed by decreased growth and increased twig and branch dieback, caused by both abiotic and biotic factors (Manion, 1981).

During the last century, there have been many reports of unexpected levels of landscape-scale tree mortality and deterioration in tree health across various North American ecosystems (Sinclair, 1965; Manion, 1981; Houston, 1987; Miller et al., 1989; Ciesla and Donaubauer, 1994). Often, causes for such phenomena are undetermined, so they are characterized using terminology such as dieback, die-off, and most commonly, decline. Specific examples of tree declines include yellow-cedar decline, aspen decline, oak decline, and more recently southern pine decline (SPD). While other declines have been studied in-depth, summarized, and critiqued (e.g., Jurskis, 2005), similar information is lacking for SPD. Due to the importance of forestry in the southern pine-dominated region, a closer examination of SPD is warranted.

Currently, there is little published information that supports the notion of SPD as a regional threat to southern pine health, and most cases of pine symptomology resembling SPD are likely a manifestation of natural tree mortality and local factors that stress trees. In this paper we examine the recently described SPD phenomenon. We begin by reviewing the history of SPD and pine decline etiology. We then evaluate the current extent and threat posed by SPD in the southern pine landscape using data collected by USDA Forest Service's Forest Inventory and Analysis (FIA) Program. On the basis of results from our FIA analyses, we place SPD in the context of common forest disturbances and, using examples from well-accepted forest declines elsewhere, outline abiotic and biotic factors that can affect pine (*Pinus* spp.) health in the southeastern U.S. Finally, we discuss research limitations related to SPD and suggest management strategies for southern pine forests that can contribute to sustained southern pine health and productivity.

2. The southern pine ecosystem

Forests in the southeastern United States are an integral component of the local, regional, and global economies, and are a diverse mosaic of hardwood and conifer tree species. Endemic pine species including loblolly (*Pinus taeda* L.), longleaf (*Pinus palustris* Mill.), shortleaf (*Pinus echinata* Mill.), and slash (*Pinus elliottii* Engelm.) pine cover ~45% of the total forested area of the southeastern U.S., of which about 42% of this area is planted and commercially managed (Wear and Gries, 2012). Loblolly pine is the dominant species across most of this region, especially in intensively managed commercial plantations. Loblolly pine is present on >12 million ha across 14 states, and this area is projected to increase to >17 million ha by 2020 (Wear and Gries, 2002).

Southeastern forests have a history of disturbance by various abiotic (e.g., wildfires, drought, flooding, and windstorms) and biotic (insect and disease outbreaks, and herbivore browsing) natural disturbances (Hanson et al., 2010). These disturbances create a complex habitat mosaic on the landscape (Turner and Ruscher, 1988), and also interact with each other to produce further landscape heterogeneity. However, anthropogenic disturbances during the last two centuries have arguably had an increasingly greater impact than natural disturbances. Fire suppression programs and subsequent changes in natural fire regimes have modified forest composition and structure across the region (Van Lear et al., 2005). Much of the area now in forest was cleared for agriculture during European settlement and the severe erosion that occurred (Trimble, 2008) profoundly changed the fertility and productivity of the land. Reforestation occurred in the 1920s (MacCleery, 1992), but in many instances the original forest cover-type and associated native species were lost. Due to changes in forest structure and composition, especially in commercial pine plantations, native pest species may have a greater impact and higher populations (e.g., increased attack rates of southern pine coneworm, *Dioryctria amatella* [Hulst], as management intensity increased; Nowak and Berisford, 2000) than in natural settings, along with an increased potential for invasion by non-native species (Sharitz et al., 1990). Southeastern forests are poised for additional alterations, as global climatic changes create new and unique combinations of plants, pests, pathogens, and abiotic conditions (Williams and Jackson, 2007; Klepzig et al., 2012).

3. Southern pine decline – A case study

In the 1950s, declining and dying mature loblolly pine stands were observed on the Oakmulgee District on the Talladega National Forest in Alabama, and a multi-year study was initiated