Detailing the Impact of High Grading on Future Forests

Science to Solutions

In Brief

Exploitative timber harvesting practices are a detriment to forest structure, composition, and biomass and carbon storage. In the eastern United States, where most forests are privately owned, the exploitative timber harvesting practice called high grading is still commonly employed, threatening future forest health and productivity. High grading is a term used to describe a type of unsustainable timber harvest whereby only the largest most economically valuable trees are removed and no consideration is given to the future health of the forest. A recent study compared the impacts of high grading to a well-established, science-informed timber harvesting practice that's used in the eastern United States to regenerate mixed-oak (mixed-*Quercus*) stands (Curtze et al. 2022a and 2022b). Results provide forest landowners and practitioners with a better understanding of the detrimental impacts of high grading and evidence and indicators necessary to reveal a forest stand's past management history and determine whether rehabilitative action should be a priority.

A History of Timber Use and Exploitation

The forests of the eastern United States have a rich utilitarian history. Prominent are land clearing events for agriculture and extensive use of valuable wood products held in the once vast and diverse forests of the region. Often, practices to harvest wood products didn't occur with a deep understanding of the natural succession of the forest, and how tree preferences for site (e.g., soil moisture) and light play into their growth in particular places. Of these practices, one of the more common, then and now, is the exploitative practice of high grading. High grading (also referred to as diameter-limit cutting or select/selective cutting) is a timber harvesting practice wherein the largest, most economically valuable trees are removed without considering the impact to the future forest. High grading is primarily problematic where forests are essentially even-aged. Forest regrowth following massive land-clearing events, such as the widespread forest clearing to create charcoal at the turn of the 20th century to support the Industrial Revolution, often results in the formation of even-aged stands. Absent from high grading are scientifically based – or silvicultural – methods that ground a timber harvest in ecology and natural succession. Silvicultural methods (e.g., shelterwood regeneration sequence, crop tree release) consider species composition, tree spacing, tree health and form, seed sources, and other attributes (e.g., soil and slope) of the current stand to ensure that a harvest supports the health, structure, and productivity of residual trees as well as those to come. Although the impacts of high grading depend on initial stand conditions, high grading tends to degrade stands by increasing the relative abundance of unhealthy and/or poorly formed trees, small-diameter trees, and less-desirable overstory tree species (Clatterbuck 2006, Curtze et al. 2022a). These residual forest conditions may limit forest management options for forest landowners and practitioners (e.g., Clatterbuck 2006, Lussier and Meek 2014, Curtze et al. 2022b), and decrease forests' abilities to remain resilient, fend off pests and pathogens, supply valuable wood products, and provide important social and ecological benefits such as carbon storage in wood (Curtze et al. 2022a) and habitat for specific wildlife species.

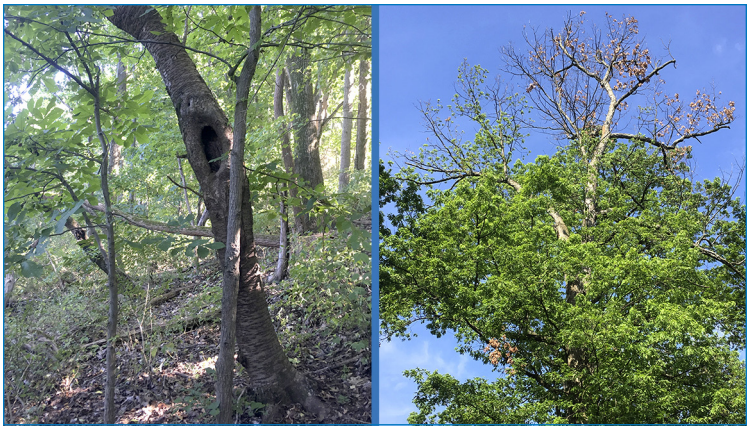
High grading is still currently one of the most common exploitative timber harvest practices occurring in the family forests (FF) of the eastern United States. Research in both Pennsylvania and West Virginia found that greater than 60% of recent commercial timber harvests on FFs were high grading timber harvests (McGill et al. 2006, Metcalf et al. 2012). The potential negative impact of such harvests on forest conservation and management is amplified by the fact that greater than 70% of forests of the eastern United States are privately owned (Butler et al. 2016). To better manage these stands now and into the future, it is important for forest landowners and practitioners to identify and understand the consequences of exploitative past practices, such that a stand can be restored and not further degraded.

Past Practices Yield Present Results — and Consequences

Recent research conducted in Pennsylvania identified the impacts of high grading on forest structure, forest composition, and biomass and carbon storage in mixed-oak forests (Curtze et al. 2022a). The researchers sought to assess the differences in forest structure, forest composition, and biomass and carbon storage between stands that were high graded and stands that received the first removal cut of a uniform shelterwood regeneration sequence ("shelterwood stands"/"shelterwood treatment" hereafter). This shelterwood treatment is one stage in a multi-stage sequence that's intended to regenerate a mixed-oak stand (Brose et al. 2008). This treatment reduces the density of trees in quantities like high grading, but it identifies healthy, high-quality stems to retain as seed sources and removes those that threaten to inhibit the seed trees' growth (Penn State Extension, 2016). Detailed below are descriptions of the important research findings that demonstrate the impact of high grading, positioned in comparison to a sustainable and science-informed harvesting method.

High Grading's Effect on Forest Structure

The high graded stands contained significantly less high-quality, well-formed (e.g., straight stem, free from defects) trees than the shelterwood stands. Average tree diameter was 7.5 inches smaller in the high graded stands compared to the shelterwood stands and there were greater proportions of large-diameter trees in shelterwood stands than in high graded stands. All of these structural characteristics combine to indicate that high grading results in stands with higher proportions of smaller, poorly formed, and unhealthy trees. These trees are more vulnerable to stress caused by insects, disease, and weather, which can lead to wood decay and defect, ultimately impacting the amount of wood that can be sold or salvaged from a stand. These stands also contain fewer economically valuable sawtimber trees (generally trees ≥ 11.5 inches in diameter at breast height (dbh), measured at 4.5 feet from the ground), which are often the same trees that serve as an important seed source and as important wildlife habitat for some species that prefer mature forest conditions (e.g., cerulean warbler *[Setophaga cerulea]*). This limits the future forest management options available, increases the costs, and minimizes the future economic return of conducting management.



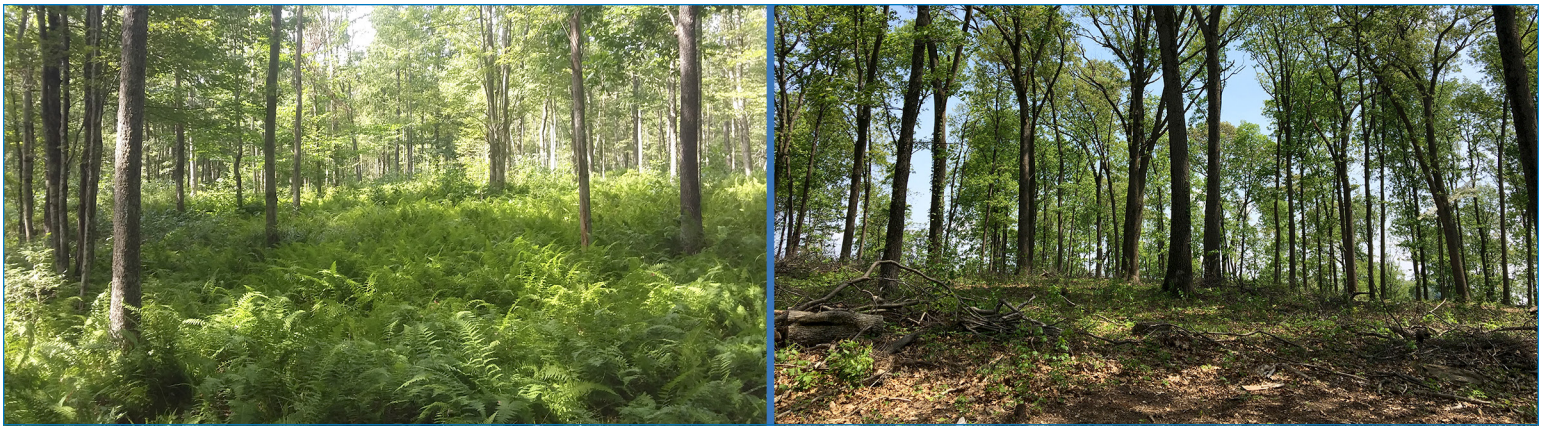
Left, poorly formed tree due to erratic stem and large cavity. Right, tree experiencing crown dieback. Photos by Alex Curtze.

High Grading's Effect on Forest Composition

The high graded stands contained 2.2 times less oak (*Quercus* spp.), 6.0 times more red maple (*Acer rubrum*), and 10.1 times more birch (*Betula* spp.) in the overstory canopy than the shelterwood stands. The amount and type of tree seedlings (i.e., young tree; definitions vary, but Curtze et al. [2022a, 2022b] considered stems less than 1.0 inches in dbh and at least 2.0 inches in height to be seedlings) is also important to consider because they represent the composition of the next forest overstory. The high graded stands also contained significantly fewer tree seedlings per acre than the shelterwood stands. Recall that high grading makes no attempt to consider the conditions of what remains in a forest, or what will grow in replacement. The compositional differences of residual stands indicate that this lack of consideration jeopardizes the conservation of mixed-oak forests. This is intensely problematic because oaks play a key role economically and socially (e.g., the provision of wood products and carbon storage) as well as ecologically (e.g., food and habitat to many wildlife species). Beyond oak, high grading generally hampers the ability of forest landowners and practitioners to regenerate healthy and productive forests.

High Grading's Effect on Forest Biomass (and Carbon)

Biomass is important in forests because woody biomass represents a product to be used in renewable energy as well as a form of carbon storage. Wood is almost entirely made of carbon and retains carbon as long as the tree is living or the wood is not decaying. Thus, the healthier the forest, the greater the productivity of high-quality wood volume and the greater the retention of biomass. On average, the high graded stands contained substantially less biomass per acre, and thus carbon, than those that received the shelterwood treatment (Curtze et al. 2022a). Biomass is related to the density of trees in a stand, tree size (diameter), tree species, and tree vigor. Biomass exponentially increases with increasing diameter, so the loss of large-diameter trees in the high graded stands contributed to the lower biomass. Additionally, a shift in overstory species composition in the high graded stands likely also contributed to the difference in biomass, since one 15.7 inch in diameter oak stem (i.e., average tree diameter in the shelterwood stands) contains roughly 375 pounds more biomass than a red maple stem of the same diameter. Biomass is also impacted by the vigor of the trees left in a stand after a harvest. High grading is often justified through the misinterpretation of what is left behind — it is assumed that tree size is related to tree age and therefore taking the largest, best trees leaves behind a smaller, younger stand of trees which will take advantage of the increased light and space to grow. However, Curtze (2021) confirmed that diameter is not always related to age, seeing that trees in the shelterwood stands were on average about 5.6 inches larger in diameter than those of the same age in the high graded stands. Essentially, high grading generally leaves behind a stand of less-vigorous trees of possibly inferior genetics that are now stressed and likely have small crowns due to years of being outcompeted by the biggest and best trees in the stand. Consequently, when a stand is high graded, the capacity of these trees to take advantage of more sun and space is compromised, and thus, they are less likely to quickly accumulate diameter and volume. Thus, the stand's overall productivity and its ability to store carbon is hampered.



Left, high graded stand. Right, stand that received a shelterwood treatment. On average, the high graded stands contained fewer oak stems in the overstory canopy, many more red maple and birch stems in the overstory canopy, and significantly fewer tree seedlings per acre than the shelterwood stands. Photo credits to Alex Curtze (left) and the Finley Center for Private Forests at Penn State (right).

Knowing the Past to Manage a Better Future

The characteristics of today's forests make it possible to reveal how stands were previously managed. A recent study by Curtze et al. (2022b) in the mixed-oak forests of Pennsylvania identified structural and compositional characteristics that can be used to reflect the type of past management that a stand received without having detailed records of preharvest stand conditions (e.g., density and species of trees) or recreating preharvest conditions using stumps. The predictive model (or tool) developed by Curtze et al. (2022b) uses the proportion of oak in the overstory, proportion of trees with good form and health, tree size (diameter), and spatial distribution of sawtimber-sized trees and of desirable tree seedlings to infer past management history. Most notably, stands with low to moderate proportions of oak in the overstory and/or low to moderate proportions of well-formed and healthy trees have a good likelihood of being classified as high graded. The predictive model also provides the user with a level of certainty about whether the stand has been high graded or received some other type of management. This can be particularly useful for forest landowners and practitioners who would like to determine the optimal allocation of staff and financial resources. Being able to differentiate a stand's current needs more accurately will save landowners and practitioners time, money and resources, and will prepare them for greater success in the sustainable management of a forest in the long-term. To learn more about treatment options for high graded stands, refer to *Treatments for Improving Degraded Hardwood Stands* (Clatterbuck 2006).

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Additional Resources:

To learn more about Natural Resource Conservation Service's Working Lands for Wildlife partnerships, visit: **nrcs.usda.gov/wildlife**

To learn more about sustainable timber harvests, forest management, and forest stewardship, contact the Center for Private Forests at Penn State, PrivateForests@psu.edu or visit ecosystems.psu.edu/private-forests.

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