Briefing Paper

Topic: Red spruce (*Picea rubens*) influence on soil organic carbon (SOC) stocks

Issue: Historic harvest of red spruce and related disturbance in the central and southern Appalachians has resulted in large losses of soil organic carbon into the atmosphere as CO_2. Recent studies suggest that restoring red spruce with targeted forest management plans could restore much of this carbon within a century while also improving regional habitat for threatened wildlife and ecosystem services like drinking water security.

- **Tree species adaptations control soil carbon buildup**: Many studies suggest that boreal ectomycorrhizal conifer species like red spruce promote large amounts of SOC buildup in forest floor and subsurface soil layers [1-4].
- **Soil respiration and carbon stocks represent more carbon than the atmosphere, vegetation and human emissions:** Soil respiration of CO_2 is an order of magnitude more than human emissions [5]. SOC stocks represent a larger pool of carbon than the atmosphere and vegetation combined globally [1,6].
- **The majority of soil carbon stocks are found in boreal conifer and tundra-permafrost regions** [6,7]: Red spruce represents the edge of these regions as it exists along the transition to temperate deciduous forest communities which favor much smaller soil carbon stocks[7]. Global shifts in this transition due to climate change and human disturbance significantly exacerbate climate change through release of soil organic carbon pools in the atmospheric CO_2 pool.
- **Historic disturbance of red spruce has caused hardwood encroachment and massive CO_2 emissions:** Studies in the southern and central Appalachians have documented red spruce range decreases of 90% or more due to timber harvest and associated fires from 1860-1940 [8-12]. This shift likely resulted in a massive release of carbon from deep organic forest floors (up to 1-meter deep) and subsurface soil layers into the atmospheric CO_2 pool that is not fully understood, and merits further research.
- **Red spruce restoration can sequester significant SOC within 80 years:** Recent data suggests that at least 6.6 Tg of carbon (equivalent to 56.4 million barrels of oil) would be incorporated in the forest floor within 80 years by managing to restore historic spruce dominated stands that were disturbed by historic timber harvest **in West Virginia alone** - a small portion of the historic red spruce range. Subsurface spodic soil horizons are also likely to incorporate additional SOC in this timeframe [13,14]. These estimates also don't include vast areas thought to have mixed spruce-hardwood forest historically, which also would accumulate more SOC if spruce was fully restored.
- **Old growth red spruce could sequester even more carbon:** Studies in similar cool moist conifer systems in the northeast U.S. show that well-structured old growth forests fix large amounts total terrestrial organic carbon [15,16]. Red spruce stands represent a similar potential for increased C stores in forest pools.
- **Red spruce forest floors will continue to sequester carbon with old growth development**: Research in West Virginia also indicates that forest floors could assimilate two to three times more SOC than the 80-year estimate if managed for old growth habitat, subsurface SOC pools would also grow.
- **Red spruce has an uncertain future, but still could prove to be resilient to climate change** : Studies have suggested that red spruce has declined because of acid deposition [17-19], but other researchers concluded that warmer temperatures might be more important [20]. However, recent studies show that red spruce stands are expanding [21,22] and had a broader pre-harvest historic extent than prior research acknowledged [12]. Therefore climate change projections that red spruce will disappear from the southern and central Appalachians within this century [23,24] should not be considered the final word on how we view red spruce restoration goals; especially in light of its potential to help mitigate climate change.

Contact: Stephanie Connolly, Forest Soil Scientist, Monongahela NF, (304)636-1800 x244 sconnolly@fs.fed.us
Travis Nauman, Ph.D. Student, West Virginia Univ., Plant and Soil Sciences, tnauman@mix.wvu.edu

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