Forest Management, Carbon, and Climate Change

A Position of the Society of American Foresters

Originally adopted on December 8, 2008, revised and renewed on December 7, 2014, and again May 2, 2020. This position statement will expire in 2025, unless, after subsequent review, it is further extended by the SAF Board of Directors.

Purpose

To clarify the increasingly complex opportunities and challenges associated with forest management for mitigating and adapting to climate change, including: carbon valuation and forest conservation, natural resources economies for ecosystem services, and risks to and opportunities for increasing the resilience of American forests and surrounding communities.

Scope

Forest management practices that conserve forestlands, sustain economies and communities, and protect our natural resources in light of anticipated climate change.

Position

The Society of American Foresters (SAF) promotes and supports science-based policies and actions that consistently recognize the positive role that forest management plays in: (1) mitigating greenhouse gas (GHG) emissions through the sequestration of atmospheric carbon in resilient, well-managed forests (trees and soil), producing wood-based products to replace both non-renewable materials and fossil fuel-based energy sources; and (2) adapting to future climate patterns through active forest management that reduces the risk of stand-replacing wildfire and other climate-driven disturbance emissions and avoids land-use changes from forests. Successfully adapting our forests and forest management practices to climate change will require explicit and long-term investments in research, education and outreach to aid in management for these changes. This includes direct monetary support to private landowners and public agencies to explore and implement the technologies and practices that can be used to mitigate carbon emissions and adapt to changing climate conditions, and associated assistance programs for local communities to implement the necessary changes.

Issue

Forests play an essential role in regulating global atmospheric GHGs while providing essential ecosystem services like clean water, wildlife habitat, recreational opportunities, and forest products that, in turn, store carbon (Deal et al. 2017, Buotte et al. 2019). Despite that role, forestry is often intentionally or unintentionally excluded from policy processes focused on carbon and climate given the complexity of accounting for the potential roles of forest management in carbon markets, regulatory uncertainty and the unintended consequences of some wood energy policies (Canadell and Raupach 2008, Johnston and Radeloff 2019). Such policy fluctuations and uncertainty have the potential to diminish the clear, known positive benefits that forests and sustainable forest management can play in stabilizing Earth’s climate (Miner et al 2014, IPCC 2018).

Forests sequester carbon at variable rates depending on species, climate, disturbance regimes and management practices, but all forests fix carbon dioxide from the atmosphere and store it, in net, for long periods (Birdsey et al. 2019). Full life-cycle carbon accounting (modeling) is difficult and often controversial since it lacks perfect empirical evidence (Kim and Dale 2011, Miner et al. 2014). Standing forests store large amounts of carbon that can contribute to climate change mitigation (e.g., Buotte et al. 2019); however, a simple comparison of carbon storage between standing forests and harvested forests ignores three fundamental issues:

1) **natural disturbances**. Disturbances continually release carbon to the atmosphere via associated tree mortality, and forests therefore can accumulate only a certain amount of carbon over time and space;
2) **market flexibility**. Carbon is not stored terrestrially by preserving a given tree or stand in one location and ignoring replacement harvests from elsewhere; and
3) **product substitutions**. Reduced wood consumption, which could increase the carbon stocks in forests, would be undesirable since carbon emissions are exacerbated by the substitution of fossil-fuel intensive products for wood. Like forests, wood products have tremendously variable life spans (Johnston and Radeloff 2019); many products have a long-term net positive impact on carbon compared to non-renewable alternatives.

Finally, changes in climate (increasing temperatures, rising sea levels, reduced/short-lived snowpack, altered precipitation patterns, and extreme weather events) have the potential to dramatically affect forests nationwide through a variety of interconnected impacts (USDA Forest Service 2012, USGCRP 2018) that are difficult to fully anticipate. These include: prolonged droughts, longer wildfire seasons, and increased incidence of pest and disease related to warmer winters that drive tree and stand mortality, all of which influence forest composition and structure. Climate-related food and water shortages have the potential to move humans into new regions and/or place more demands on our nation’s forests. These changes *already* have been associated with increasing temperatures and concentrations of atmospheric carbon dioxide (CO_2) and other GHGs in the atmosphere (IPCC 2018); all global circulation models project future increases in temperature.

Background

Two active, complementary forest management approaches are fundamental to addressing climate change:

1) **mitigation**, in which forests themselves and resultant forest products are used to sequester carbon, forest biomass is used to provide substitute renewable energy, and GHG emissions are avoided through complementary product substitution (wood for carbon-intensive fossil fuel consumer goods) and resilient forest composition and structure; and
2) **adaptation**, which involves positioning forests and their associated benefits (above) in order to become more resistant and resilient to uncertain future disturbances as they become more likely in the face of changing climate conditions.

Mitigation: Carbon Sequestration

Forests sequester carbon as a function of site productivity and the potential size of various carbon storage pools: soil, charcoal, litter, downed wood, standing dead wood, and live stems, branches, and foliage. Sequestration capacity depends on stand density, tree species and sizes, tree and stand vigor and longevity, soil disturbance, tree mortality, wildfires, insects, and diseases. Forest management that regulates composition and structure prudently over time and space, balancing tree retention and removal, simultaneously stores carbon in both intact forests and renewable carbon-smart products (e.g., lumber, engineered composites, paper, and byproduct energy) with its associated socioeconomic benefits. Above all, enhancing the role of forests in reducing GHG emissions through sequestration requires keeping forests as forests and, where appropriate, increasing the forestland base through afforestation and restoration of degraded lands.

Traditional silvicultural treatments focused on wood, water, wildlife, and aesthetic values are fully amenable to enhancing carbon storage and reducing emissions from forest management (Tappeiner et al. 2015). Choices regarding even-aged or uneven-aged management regimes, species composition, slash disposal following harvests, site preparation, timing and intensity of intermediate harvests, fertilization, and rotation length/entry cycles can all be modified to increase carbon storage and reduce carbon emissions. In particular, improving the ecological resistance and resilience of fire-adapted ecosystems enhances long-term sequestration through avoided loss to wildfire (Finkral and Evans 2008). Prudent forest management and wood utilization sustain high levels of carbon stored in large landscapes over long time periods.

Mitigation: Solid Wood Product Substitution

Substituting solid wood products for fossil-fuel-intensive products can reduce GHG emissions in several important ways. Life-cycle analyses consistently show that lumber, wood panels, and other solid wood products store more carbon, emit less GHGs, and use less fossil-fuel energy than steel, concrete, brick, or vinyl, whose manufacture is energy intensive and produces substantial emissions (Lippke et al. 2004, Malmsheimer et al. 2011). Harvesting temporarily reduces carbon sequestration in the forest by removing biomass and disturbing the soil, but much of the removed biomass is subsequently stored in forest products or otherwise used to substitute for fossil-fuel products or energy. The carbon in lumber and furniture may not be released for many decades; paper products have a shorter life.

Storage of carbon in harvested wood products is gaining recognition in domestic climate mitigation programs, though the accounting for the carbon through a product's life cycle is complex (Johnston and Radeloff 2019). Solid wood product substitution, however, provides long-term carbon storage that when combined with appropriate waste and landfill management can further delay the conversion of wood to GHG emissions, or provide waste wood for power generation to reduce the need for fossil fuel generation.

Mitigation: Woody Biomass Substitution

The use of woody biomass from forests to produce energy and biochemical products opens two additional opportunities to reduce GHG emissions (see our associated Position Statement on *Utilization of Woody Biomass for Energy*). One involves using biomass for combined heat and power (CHP) rather than allowing low-value forest residues to accumulate and decay on site or removing them by open burning. Hundreds of millions of tons of biomass could be generated annually from logging residues, treatments to reduce fuel buildup in fire-prone forests, treatments to improve forest health, fuelwood harvests, forest products industry waste, urban wood residues, and energy plantations (US Department of Energy 2016). Biomass can be burned directly, mixed with coal, or added to oil- and gas-generated electric production processes to reduce GHG emissions (Xi Lu et al. 2019); any such use of biomass for energy can reduce regional dependence on coal, natural gas, diesel, and/or heating oil imports.

The second opportunity is substitution of forest biomass as a feedstock for biofuels and biochemicals, which can be substituted for fossil-derived fuels and chemical production. Fossil-fuel chemical products introduce new, additive pollutants into the atmosphere, whereas biogenic emissions are re-sequestered over time. Substituting cellulosic biomass for fossil fuels greatly reduces carbon emissions (US EPA 2007). Further, the use of forest biomass enhances domestic and regional economic development by supporting rural economies and fostering new industries making value-added bio-based products.

Bioenergy with Carbon Capture and Storage (BECCS) has been a recent addition to global bioenergy strategy due to the potential to intercept CO_2 emissions associated with biomass combustion for CHP and permanently store this CO_2 in geological formations (e.g., aquifers). Technological challenges remain, but BECCS has gained traction through inclusion in three of the four illustrative model pathways outlined in the IPCC Special Report on Global Warming of 1.5°C.

Mitigation: Reducing Wildfire and Disturbance Emissions

Active forest management, including prescribed burning, and wildland fire management strategies that reduce fire intensity and restore forest health can dramatically reduce GHG emissions (e.g., Bonnicksen 2008; see our associated Position Statement on *Wildland Fire Management*). The ten-year mean number of acres burned annually across the United States is approaching 7 million for the past decade (NIFC 2019); the cumulative emissions from these fires is large, and altering the intensity of these fires represents an opportunity to significantly reduce emissions. Climate change models forecast an increase in wildfire activity (IPCC 2018), exacerbated by climate change and increased accumulations of hazardous forest fuels causing ever-larger wildfires. Wildfires burning with more intensity can then lead to unintended consequences of changes in vegetative makeup and subsequent reduction in carbon sequestration (Westerling et al. 2006).

Concurrently, bark beetle outbreaks across western North America increase dead wood loading that releases large amounts of GHG emissions as it decays, and can lead to increased severity of wildfires when that loading subsequently burns and reburns. Such disturbances are projected to increase with warming climate conditions (Hicke et al. 2012). Canada estimates that their bark beetle outbreak shifted its land use carbon inventory from sequestering CO_2 to becoming a net emitter (Kurz et. al. 2008).

Mitigation: Avoiding Land-Use Change

Preventing the conversion of forestlands to non-forest uses is another way to reduce GHG emissions (Canadell and Raupach 2008; see our associated Position Statements on *Parcelization, Fragmentation and the Loss of Private Forestland in the US* and *Forest Offset Projects in a Carbon Trading System*). Conversion of forestlands globally released an estimated 136 billion tonnes of carbon, or 33 percent of the total emissions, between 1850 and 1998, more emissions than any other anthropogenic activity besides energy production (Watson et al. 2000). Forest conversion and land development releases carbon from loss of forest biomass, both aboveground vegetation and tree roots, as well as belowground soil stocks. In the United States, a major threat to forestland is the rise in land values for low-density development. Landowners generally convert forestland to residential and commercial uses to capture increasing land values or avoid reforestation costs post disturbance.

Several options exist to slow the rate of private forestlands being converted to non-forest uses. Easement acquisitions provide one method to encourage landowners to keep forests as forests. New and stable product markets also provide positive incentives to landowners (Miner et al. 2014). Viable wood products markets that recognize the benefit of carbon storage and sequestration provide positive incentives for forestland ownership. Sustainable utilization of working forests for a combination of wood products can improve forest landowners' returns on their land, bolster interest in forest management, and thus prevent conversion to other uses.

Adaptation: Resistance, Resilience and Assisted Migration

Resistance and resilience of current and future forests can be enhanced through prudent pro-active forest management of existing tree species and stands, including restoration of structure and composition when current conditions are outside a range of desired conditions (Tappeiner et al. 2015). For example, there are millions of acres of dense, fire-excluded dry forest types of the American West needing some fuel reduction treatment (mechanical and prescribed fire) in advance of dry climatic patterns and wildfire. These treatments allow for the marginal, progressive adjustment of forest conditions, which are largely consistent with professional forestry standards but can be more quickly implemented in anticipation of emerging, rapid climatic shifts.

More controversial techniques include actively assisting species/genetic material migration to facilitate transitions to new locations and new conditions faster than would happen naturally (Williams and Dumroese 2013). Assisted migration has the potential to expand the available genetic diversity for future conditions, encouraging better-adapted species mixtures and gene stocks, and provide new locations for genetic material (i.e., future refugia). These practices are rooted in traditional reforestation and afforestation practices (e.g., seed zones and transfer guidelines) but will require a commitment to new research, education, and outreach as the profession moves forward. Many scientific, policy and ethical concerns exist about risk of expediting the movement of some plant materials, including distraction from other simpler conservation and mitigation strategies, genetic pollution and hybridization, introduction of new pests and pathogens, and future impairment of ecosystem function (Williams and Dumroese 2013).

References

Birdsey, R.A., A.J. Dugan, S.P. Healey, K. Dante-Wood, F. Zhang, G. Mo, J.M. Chen, A.J. Hernandez, C.L. Raymond, and J. McCarter. 2019. *Assessment of the influence of disturbance, management activities, and environmental factors on carbon stocks of U.S. national forests.* USDA Forest Service Gen. Tech. Rep. RMRS-GTR-402, Rocky Mountain Research Station, Fort Collins, CO. 116 pages plus appendices.

Bonnicksen, T.M. 2008. *Greenhouse gas emissions from four California wildfires: Opportunities to prevent and reverse environmental and climate impacts.* FCEM Report 2. The Forest Foundation, Auburn, CA.

Buotte, P.C., B.E. Law, W.J. Ripple, and LT. Berner. 2019. Carbon sequestration and biodiversity co-benefits of preserving forest in the western USA. *Ecol. Applic.* 30(2):e02039.

Canadell, J.G. and M.R. Raupach. 2008. Managing forests for climate change mitigation. *Science* 320:1456-1457.Available online at http://dx.doi.org/10.1126/science.1155458.

Deal, R., L. Fong, and E. Phelps (tech. eds.). 2017. *Integrating ecosystem services into national Forest Service policy and operations.* USDA Forest Service PNW-GTR-943, Pacific Northwest Research Station, Portland, OR. 87 p.

Finkral, A.J., and A.M. Evans. 2008 The effects of a thinning treatment on carbon stocks in a northern Arizona ponderosa pine forest. *For. Ecol. Manage.* 255(7):2743-2750.

Hicke, J.A., C.D. Allen, A. Desai, M. Dietze, R.J. Hall, E.T. Hogg, D. Kashian, D. Moore, K. Raffa, R. Sturrock, and J. Vogelmann. 2012. The effects of biotic disturbances on carbon budgets of North American forests. *Global Change Biol.* 18:7-34.

IPCC. 2018. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.). World Meteorological Organization, Geneva, Switzerland. 32 pp. Available online at https://www.ipcc.ch/sr15/.

Johnston, C.M.T., and V.C. Radeloff. 2019. Global mitigation potential of carbon stored in harvested wood products. *Proc. Natl. Acad. Sci.* 116(29):14526-14531.

Kim, S., and B.E. Dale. 2011. Indirect land use change for biofuels: testing predictions and improving analytical methodologies. *Biomass Bioenerg.* doi:10.1016/j.biombioe.2011.04.039.

Kurz W.A., C.C Dymond, G. Stinson, G.J. Rampley, E.T. Neilson, A.L. Carroll, and L. Safranyik. 2008. Mountain pine beetle and forest carbon feedback to climate change. *Nature* 452:987–990.

Lippke, B., J. Wilson, J. Perez-Garcia, J. Bowyer, and J. Meil. 2004. CORRIM: Life-cycle environmental performance of renewable building materials. *For. Prod. J.* 54(6):8–19.

Malmsheimer, R.W., J.L. Bowyer, J.S. Fried, E. Gee, R.L. Izlar, R.A. Miner, I.A. Munn, E. Oneil, and W.C. Stewart. 2011. Managing forests because carbon matters: Integrating energy, products, and land management policy. *J. For.* 109(7):7–50.

Miner, R., R.C. Abt, J.L. Bowyer, M.A. Buford, R.W. Malmsheimer, J. O'Laughlin, E.E. O'Neil, R.A.

Sedjo, and K.E. Skog. 2014. Forest carbon accounting considerations in US bioenergy policy. *J. For.* 112(6):591-606.

National Interagency Fire Center (NIFC). 2019. *Fire information.* Available online at https://www.nifc.gov/fireInfo/nfn.htm.

Tappeiner, J.C., D.A. Maguire, T.B. Harrington and J.D. Bailey. 2015. *Silviculture and ecology of Western U.S. Forests.* 2nd ed. Oregon State University Press, Corvallis, OR. 440p. ISBN 978-0-87071-803-8.

US Department of Agriculture Forest Service. 2012. *Future of America's forest and rangelands: Forest Service 2010 Resources Planning Act Assessment.* GTR WO-87. Washington, DC.

US Department of Energy. 2016. *2016 Billion-ton report: Advancing domestic resources for a thriving bioeconomy, Volume 1: Economic availability of feedstock.* US Department of Energy, ORNL/TM-2016/160, Oak Ridge National Laboratory, Oak Ridge, TN.

US Environmental Protection Agency (EPA). 2007. *Greenhouse gas impacts of expanded renewable and alternative fuels use.* EPA 420-F-07-035, Office of Transportation and Air Quality, Washington, DC.

USGCRP. 2018: *Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment, Volume II: Report-in-Brief.* Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.). US Global Change Research Program, Washington, DC. 186 pp. doi: 10.7930/NCA4.2018.RiB.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western US forest wildfire activity. *Science* 313:940-943. (10.1126/science.1128834)

Watson, R.T., I.R. Noble, B. Bolin, N.H. Ravindranath, D.J. Verardo, and D.J. Dokken. 2000. *Land use, land use change and forestry. Intergovernmental Panel on Climate Change Special Report.* Available online at www.grida.no/climate/ipcc/land_use.

Williams, M.I, and R.K. Dumroese. 2013. Preparing for climate change: forestry and assisted migration. *J. For.* 111(4):287-297.

Xi Lu, L.C., H. Wang, W. Peng, et al. 2019. Gasification of coal and biomass as a net carbon-negative power source for environment-friendly electricity generation in China. *Proc. Natl. Acad. Sci.* 116(17):8206-8213.