Rio Grande National Forest – Assessment 4
Carbon

Introduction

Human activities such as fossil fuel burning, industrial activities, land-use change, and agriculture lead to increases in atmospheric concentrations of greenhouse gases. Greenhouse gases contribute to the "greenhouse effect" and cause the surface temperatures of the Earth to increase and alter precipitation and other weather patterns. Global atmospheric concentrations of greenhouse gases have increased substantially as a result of human activities since 1750, and now greatly exceed pre-industrial values (IPCC 2014).

The Forest Service recognizes the important role that forest carbon sequestration plays in mitigating greenhouse gas emissions. Forests and other ecosystems are often carbon sinks. Plants remove carbon dioxide from the atmosphere and store it through photosynthesis. Carbon uptake by forests in the United States, offsets about 13 percent of our national carbon dioxide emissions each year (US EPA 2013). However, disturbances, such as fire, insects and disease, and unsustainable forest management practices, can turn forests into sources of greenhouse gases.

Forests are important carbon sinks and generally remove more carbon dioxide from the atmosphere than they emit (Pan et al.2011). Carbon stored in U.S. forests is projected to peak between 2020 and 2040 and then decline through 2060. This decline will be primarily due to removal of trees as private forest lands are converted to urban and other developed land uses (USDA 2012). The Rio Grande National Forest, and other Western forests, may emit greater amounts of carbon dioxide if wildfire and insect disturbance increase as expected, due to climate change and other stressors (Vose et al. 2012).

The Rio Grande National Forest is part of the larger system of National Forests and Grasslands. National Forests constitutes one-fifth (22 percent) of the Nation's total forested land area and contains one-fourth (26 percent) of the total carbon stored in all U.S. forests, excluding interior Alaska. Management of these lands plays an important role in carbon sequestration and the carbon cycle. However, forests and ecosystems are dynamic systems and the future trajectory of carbon stocks remains uncertain due to the variability of conditions and disturbance regimes such as wildfire, insect outbreak, and extreme weather across the U.S.

Reductions in carbon stocks may be slowed through forest protection and conservation strategies that retain forest land from conversion to non-forest uses, such as agriculture or development. This is more often associated with private land management, rather than federal lands that generally protected and sustainably managed. Long-term forest management can help restore and maintain resilient forests that are better adapted to a changing climate and other stressors.

Wood products are also important when considering carbon benefits from forests. Forest restoration and other treatments that generate wood products, such as lumber and furniture, transfer ecosystem carbon to the harvested wood products pool. Using wood for building materials, instead of concrete, steel, or plastic, can have an overall carbon benefit. Forest vegetation treatments also generate excess material (woody biomass) which can displace tradition fossil fuels. Carbon management is an important emerging theme in forest management.

Carbon Assessment Units, Assumptions, and Uncertainty

Carbon assessments can help forest managers understand how much carbon is currently stored in forest ecosystems and harvested wood products and how the potential to reduce atmospheric greenhouse gases may be influenced by management activities and disturbance regimes. The U.S. Forest Service has developed forest carbon assessment whitepapers for each region and National Forest. The Rio Grande

National Forest carbon assessment is based on forest inventory and analysis data and uses a 1990 – 2013 baseline.

This assessment commonly uses the Teragram (Tg) as a unit of measure. A Tg is not a common form of measurement for most people. One Tg is equivalent to 1,000,000,000 kg, or 1,000,000 metric tons. To put this into context, the Golden Gate Bridge in San Francisco – a steel structure 1.7 miles long, 90 feet wide, and 746 feet tall - is understood to weigh about 1 Tg. The Empire State Building in New York City, is believed to weigh about 0.33 Tg (one-third of one Tg).

As part of this process, assessment data for the Rio Grande National Forest has been disaggregated from the national inventory. The forest inventory and analysis inventory was initially designed to track basic information, including forest cover. The forest inventory and analysis now reports on status and trends in forest area and location; species, size, and health of trees; total tree growth, mortality, and removals by harvest; wood production and utilization rates by various products; and forest land ownership.

Because forest inventory and analysis was designed to capture data at the national level, there is tremendous uncertainty about inferences made at the forest-level, such as the Rio Grande National Forest. At the national scales, uncertainty of carbon flux is between 20-30 percent. Therefore, at the forest-level, the uncertainty can be much higher. Other sources of uncertainty include sampling error (estimates are based on a network of plots), measurement error (such as species identification), and model error (tree volume models and carbon pool estimates and changes in sample design over time).

Although uncertainty is high, ongoing research is focused on reducing these uncertainties over time. As time goes on, we will have better carbon estimates for the Rio Grande National Forest. Uncertainty around the carbon estimates should not prevent local managers from using this as a baseline and engaging the public around this non-market benefit of sequestered carbon.

This report meets the requirement for using existing information to assess carbon stocks during the assessment phase of the forest plan revision process. A companion assessment that describes the influence of disturbance and management activities is being developed for each National Forest. Although the companion assessment is currently unavailable, it will likely be completed by the end of 2016. This document will provide a more complete picture of carbon dynamics on the Rio Grande National Forest. It will be included in the project record for the plan revision and incorporated into the analysis, as appropriate.

The Rio Grande National Forest carbon assessment does not include emissions from agency, contractor, or permittee business operations or public recreation uses. Only forest ecosystem carbon stocks and harvested wood product pools are included in this assessment, consistent with EPA reporting categories and availability of data. Carbon emissions from internal, agency business operations are inventoried annually per Executive Order 13514 and reported to USDA. A summary of the latest Forest Service greenhouse gas inventory for business operations is included in the FY12 Sustainable Operations Collective Accomplishment Report.

Rio Grande National Forest Carbon Assessment

The Rio Grande National Forest contains approximately 75 Tg of total forest ecosystem carbon. This has increased slightly over the duration of the forest inventory and analysis sampled from 1990 to 2012. To put this in context, all National Forests within Colorado contain approximately 549 Tg, and all National Forests and Grasslands within the Rocky Mountain Region (CO, NE, SD, and part of WY) contains about 863 Tg. Total carbon in National Forests in the Rocky Mountain Region has increased slightly from 829

Tg in 1990. All private forests in Colorado have approximately 151 Tg (measurement from 2014, but displayed on the graph below for comparison purposes).

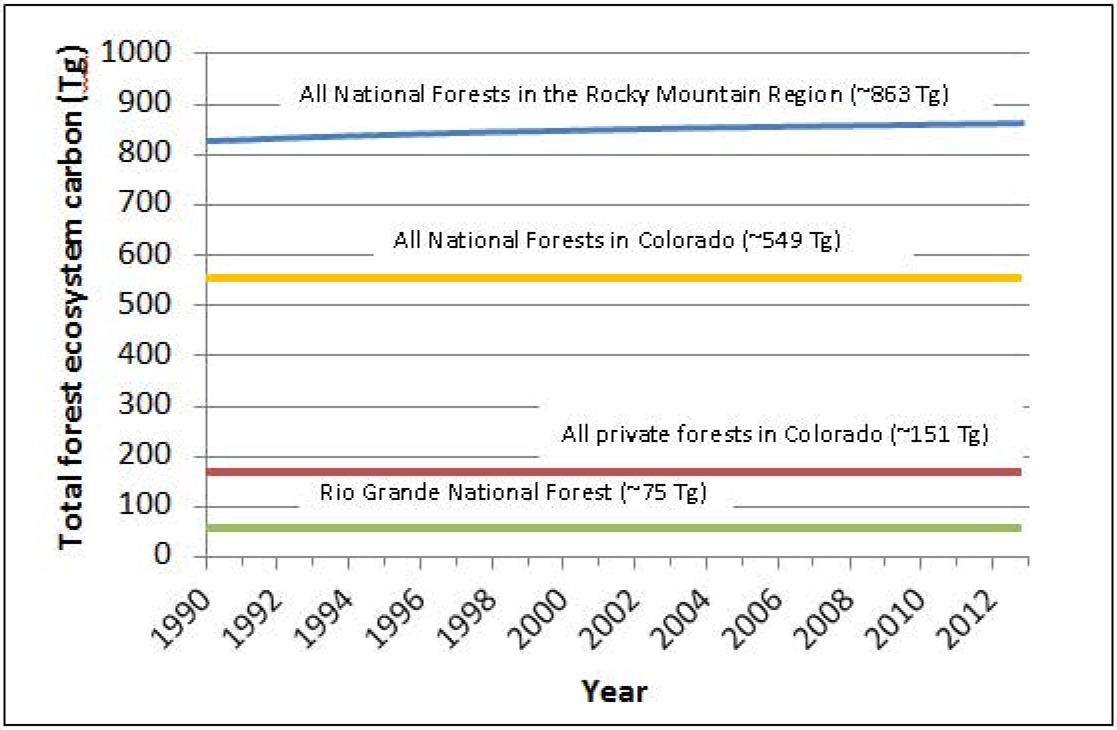

Figure 1. Selected categories of total ecosystem carbon by ownership. All data derived from FIA forest inventory and analysis

Total forest ecosystem carbon (in all seven pools) stored in the Rocky Mountain Region has increased between 1990 and 2013. The assessment combines carbon stocks from seven different carbon pools: 1) above ground; 2) below ground; 3) standing dead; 4) understory; 5) down dead; 6) forest floor; and 7) soil carbon:

1. Live trees include all live woody vegetation at least 1 inch in diameter at breast height (dbh). Separate estimates are made for both above-ground and whole-tree biomass, which includes all living biomass of coarse living roots more than 2 mm in diameter. Calculations are based on the component ratio method which is a function of volume, species and diameter of individual trees defined in Woodall et al. (2011). An estimate for foliage is added to the above ground biomass calculations.
2. Below ground live-tree carbon is based on the differences between whole trees and above ground only.
3. Standing dead trees are nonliving but follow the same definition as live trees, including coarse nonliving roots more than 2 mm in diameter. Calculations follow the basic component ratio method applied to live trees (Woodall et al. 2011) with modifications to account for decay and structural loss.
4. Understory includes all live herbaceous vegetation and woody vegetation up to 1 inch dbh. Estimates of carbon density are based on information outlined by Birdsey (1996) and calculations are based on the equation below defined in Jenkins et al. (2003).In this equation, "ratio" is the ratio of understory carbon density (Mg C/ha) to live tree C density (above- and below-ground) according to Jenkins et al. (2003) and expressed in Mg C/ha.

5. Down dead wood, also known as coarse woody debris, includes all nonliving woody biomass with a diameter of at least 7.5 cm at transect intersection lying on the ground. This pool also includes stumps and coarse roots more than 2 mm in diameter. Nonliving vegetation that otherwise would fall under the definition of understory is included in this pool. Ratio estimates of down dead wood follow regional and forest type classifications described in Smith et al. (2003) and Domke et al. 2013.
6. Forest floor includes the litter, fumic, and humic layers and all nonliving biomass with a diameter less than 7.5 cm at transect intersection lying on the ground above the mineral soil. The equations defined in Smith and Heath (2002) describes processes for decay or loss of forest floor following harvest and the net accumulation of new forest floor material following stand growth.
7. Soil organic carbon includes all organic material in soil to a depth of 1 meter but excluding the coarse roots of the pools mentioned earlier. Estimates are based on the National State Soil Geographic (STATSGO) spatial database (USDA 1991), and the approach outlined in Amichev and Galbraith (2004).

Region-wide, the amount of carbon (Tg) stored in the understory, standing dead, down dead, forest floor and soil organic carbon increased between 1990 and 2013, as shown below. The above ground pool stores the highest amount of carbon compared to the other pools.

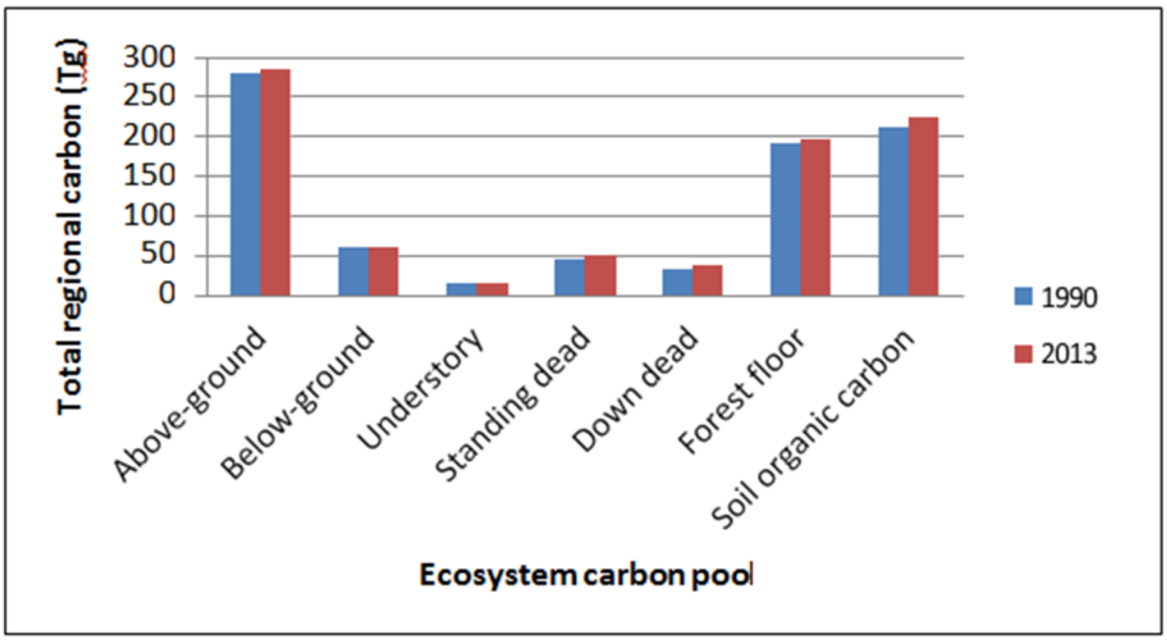

Figure 2. Carbon stocks in the seven forest ecosystem pools in national forest lands of the Rocky Mountain Region for 1990 and 2013

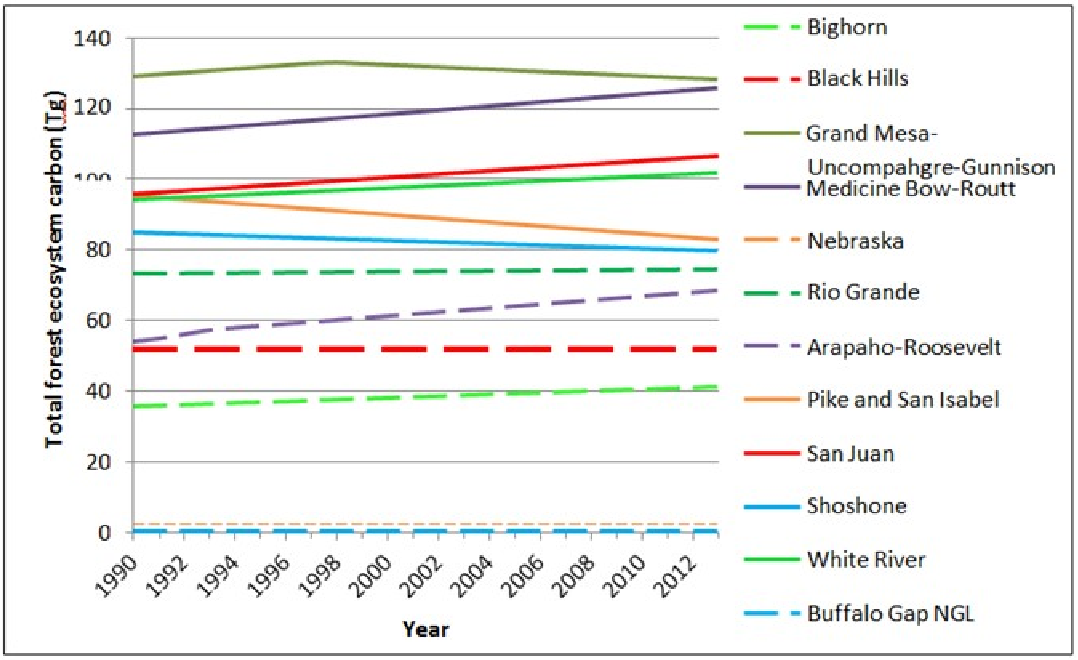

Figure 3. Total ecosystem carbon for each National Forest and Grassland in the Rocky Mountain Region

The Grand Mesa-Uncompahgre-Gunnison National Forest stored the largest amount of carbon in the region, approximately 129 Tg in 1990, peaking in 1998 with 133 Tg and reaching 128 Tg in 2013. During this period, the Bighorn, Medicine Bow-Routt, Nebraska, Rio Grande, Arapaho-Roosevelt, San Juan and White River national forests generally increased in total forest ecosystem carbon, while the Pike and San Isabel and Shoshone national forests generally decreased. Total forest ecosystem carbon in the Black Hills National Forest fluctuated slightly and the Buffalo Gap National Grassland stayed the same.

Timber Production and Harvested Wood Products in the Rocky Mountain Region

Timber harvests are typically discussed and reported in volumetric terms of cubic feet, or board feet. However, these numbers can be easily converted to carbon stored. Between 1906 and 1931annual timber harvests in the Rocky Mountain Region remained below 0.235 Tg. Harvests began to increase thereafter through the 1960s, and declined in the early 1970s and 80s. Annual harvest levels remained between 0.400 Tg and 0.700 Tg from the early 1980s to the mid-1990s, peaking in 1988 at 0.690 Tg. Beginning in the early 1990s, harvest volumes declined, to a low in 2003 of less than 0.176 Tg. Slight increases have occurred since 2003; however harvest levels have remained below 0.350 Tg.

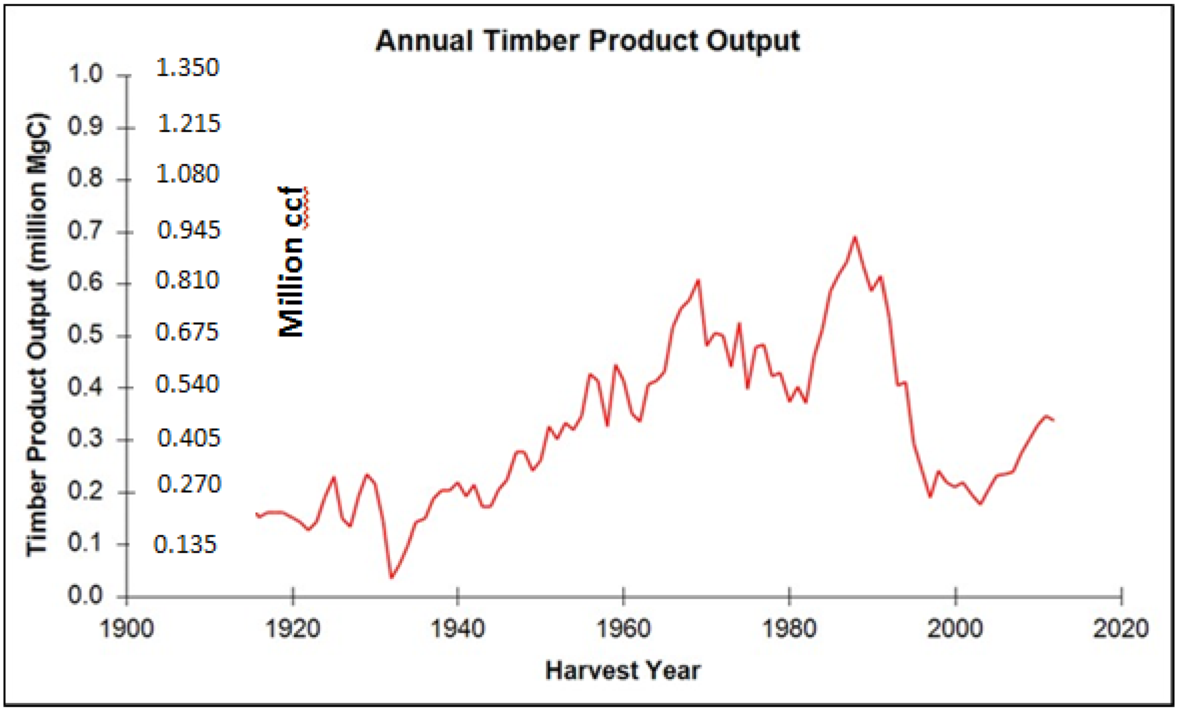

Figure 4. Annual timber product output in the Rocky Mountain Region, 1906 to 2012. Harvest estimates are based on data collected from USDA Forest Service Archives and Cut/Sold reports (Stockmann et al. 2014). (One million MgC = One Tg)

Nationwide, about 5 percent of forest carbon stocks are contained in harvested wood products. Although harvested wood products are small compared to ecosystem carbon, it is an important component of national level carbon accounting and reporting. As defined by the Intergovernmental Panel on Climate Change (IPCC), harvested wood products are products made from wood including lumber, panels, paper, paperboard, and wood used for fuel (Skog 2008). The harvested wood products carbon pool includes both products in use and products that have been discarded to landfills, or solid waste disposal sites. Emissions from harvested wood products occur through decay and combustion of wood products.

For the Rocky Mountain Region, harvested wood products increased in the early 1950s until plateauing in 2005 and peaking in 2013 with approximately 12 Tg. In the context of total forest carbon, including both ecosystem carbon and harvested wood products carbon, the Rocky Mountain Region harvested wood products carbon stocks represent roughly 1.37 percent of total forest carbon storage associated with national forests in the Rocky Mountain Region in 2013.

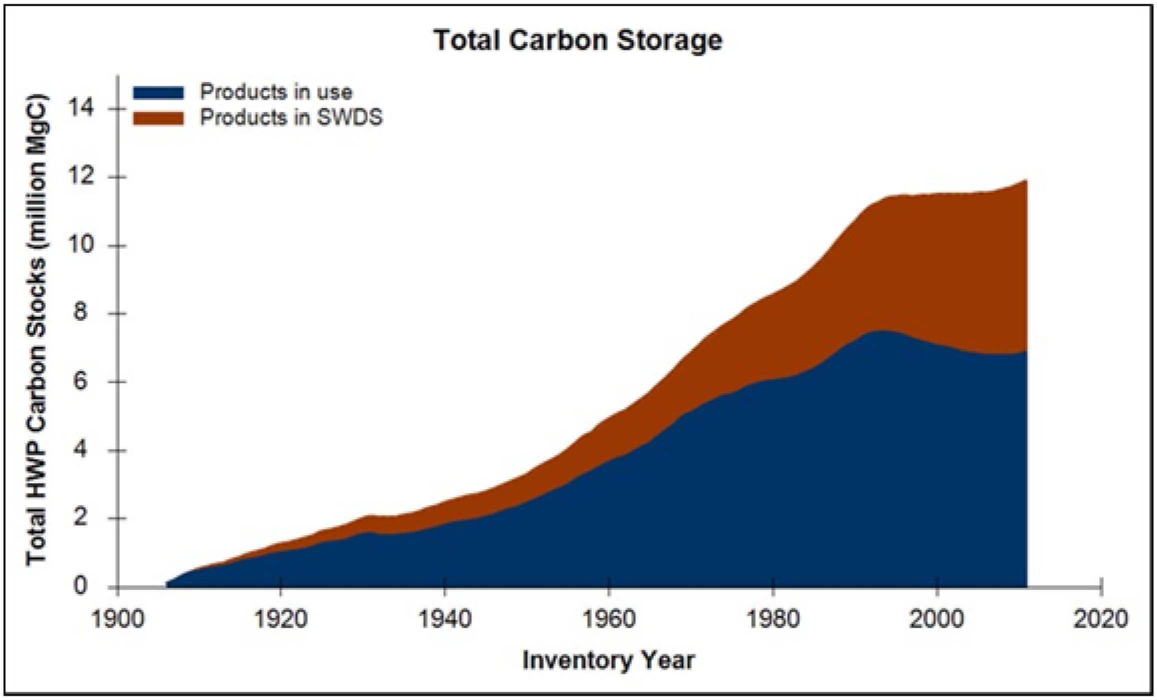

Figure 5. Carbon stored in harvested wood products, manufactured from Rocky Mountain Region timber. Carbon in harvested wood products includes both products that are still in use and carbon stored at solid waste disposals sites, including landfills and dumps (Stockmann et al. 2014).

Modeling under this approach also has uncertainty. In some cases, historic annual harvests have been adjusted to account for land exchanges, divestments, acquisitions, and consolidations. Conversion factors, and the ratios used for timber products and end uses have also changed over time. Since few old records for these ratios exist, recent averages were applied retrospectively.

The carbon in harvested wood products from timber products is based upon historic data from several regions of the U.S., which tracked how wood flowed from harvested timber products to primary products to end-uses (Smith, et al. 2006). Fuelwood products are assumed to have full emissions with energy capture in the year they were produced. Carbon from burned and discarded products is assumed to be emitted without energy capture. The approach does not account for the difference between methane and CO_2 emissions from landfills in terms of CO_2 equivalents. Furthermore, this approach does not account for product substitution, or emissions from harvest or transportation, which are thought to represent a relatively small fraction of the carbon stored in harvested wood products pools (Healey et al. 2009, Loeffler et al. 2009).

The Future of Western Forest Carbon Stocks

The future of the terrestrial carbon sink of western forests, including the Rio Grande National Forest, is uncertain due to the multiple interacting factors that influence carbon stocks and fluxes (Lenihan et al. 2008a; Ryan et al. 2008; King et al. 2007; Pacala et al. 2007; Birdsey et al. 2007). These factors include climate variability and change; potential positive effects of increased atmospheric CO2 concentrations on plant productivity; frequency, duration, and severity of moisture stress; changes in the rate and severity of natural disturbances; and land management practices (Canadell, Pataki et al. 2007).

Projections of the future of the U.S. carbon sink based on national trends in land-use change and fire suppression indicate that the U.S. carbon sink will decline over the 21st century due to a slowing of ecosystem recovery from 19th century land use and vegetation response to 20th century fire suppression (Hurtt et al. 2002). This analysis, which does not include projected climate change, also concluded that U.S. forests would convert to a large carbon source if fire suppression is ineffective in the 21st century.

Modeling experiments based on projected changes in climate, but not land use, suggest that the future strength of the U.S. carbon sink is very sensitive to the degree of change in climate, particularly precipitation, and fire regimes (Bachelet et al. 2001; Lenihan et al. 2008). If precipitation increases and temperature increases are small or moderate, net ecosystem productivity and carbon stocks are expected to increase. Conversely, if climate changes result in decreased precipitation and soil moisture during the growing season, net ecosystem productivity is expected to decline due to drought stress and may result in a net carbon source to the atmosphere (Lenihan et al. 2008). Increasing concentrations of atmospheric CO_2 may moderate these impacts by enhancing vegetation productivity and water use efficiency, at least up to a point where nutrient limitations and increasing temperatures overwhelm the beneficial effects of CO_2 concentrations (Bachelet et al. 2001; Joyce and Nungesser 2000; Lenihan 2008; Fishlin et al. 2007). Increases in annual area burned may further reduce net ecosystem productivity and carbon stocks despite the potentially positive effects of increasing CO_2 concentrations (Lenihan et al. 2008).

Growth rates may increase in high-elevation forests during years with earlier spring snowmelt, abnormally warm annual temperatures, and longer growing seasons. These results suggest that projected changes in regional climate will likely result in increased productivity and carbon stocks of high-elevation forests.

Prolonged periods of water stress significantly reduce a tree’s ability to photosynthesize (Kozlowskie and Pallardy 1997). As a result, climate projections with increased frequency of reduced snowpack, earlier spring snowmelt, increased temperatures during the growing season, and little or no significant increase in summer precipitation likely will result in reduced forest productivity and carbon sequestration (Boisvenue 2007; Boisvenue and Running 2010). Recent research suggests that regional warming and water balance deficit trends over the late 20th century are contributing to rapid and widespread increases in mortality rates and slight decreases in forest density and basal area in old growth forest throughout the western United States (van Mantgem et al. 2009).

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