Carbon Storage and Sequestration

Introduction

The Forest Service recognizes the vital role that our nation's forests and grasslands play in carbon sequestration. Accordingly, carbon storage and associated climate regulation has been identified as a key ecosystem service provided by the Custer Gallatin. This section of the EIS addresses and compares the existing conditions and expected trends of carbon pools on the Custer Gallatin, specifically the aboveground carbon pool. The potential effects of alternatives are analyzed relative to carbon storage (sequestration) potential.

The current levels of carbon dioxide in the atmosphere far exceed the concentrations found over the past 650,000 years (Ryan et al. 2010b). As a result, global surface temperatures have increased since the late 1800s, with the rate of warming increasing substantially. This warming will have an impact on the earth's climate, climate variability, and ecosystems (IPCC 2007). The effects of climate change observed to-date and projected to occur in the future include changes in temperature, precipitation, and disturbance patterns that drive and stress ecosystems and the benefits they provide, including degraded air quality, water resources, wildlife, carbon storage, and the quality of recreational experiences. Refer to the Terrestrial Vegetation section of this document for a summary of possible climate trends and projections relevant to the Custer Gallatin's ecosystems. Carbon sequestration is one way to mitigate greenhouse gas emissions by offsetting losses through capture and storage of carbon. The relationship between climate change and other resources is addressed throughout this analysis. In the context of global atmospheric carbon dioxide (CO_2), even the maximum potential forest management levels described by the plan alternatives would have a negligible effect on global emissions and climate. This analysis considers the potential effects of management actions on climate change as indicated by consideration of changes in carbon sequestration and storage arising from natural and management driven processes.

Regulatory Framework

There are no applicable legal or regulatory requirements or established thresholds concerning management of forest carbon or greenhouse gas emissions. The 2012 Planning Rule and regulations require an assessment of baseline carbon stocks and a consideration of this information in management of the national forests (FSH 1909.12.4).

Key indicators:

- Carbon pools (carbon stocks), carbon uptake, CO_2 emissions
- Natural and human-caused influences on carbon stocks, uptake, and emissions

Methodology, Analysis Process and Information Sources

The affected environment section summarizes the revised Forest Carbon Assessment for the Custer Gallatin NF which is included in the project record. The carbon assessment draws largely from two recent U.S. Forest Service reports: the Baseline Report (U.S. Department of Agriculture 2015) and the Disturbance Report (Birdsey et al. 2019). These reports provide assessments of forest ecosystem and harvested wood product (HWP) carbon stocks and flux, and the factors that have influenced carbon dynamics. The Resource Planning Act (RPA) assessment (USDA Forest Service 2016) and a regional vulnerability assessment (Halofsky et al. 2018a;b) also provide information on potential future carbon conditions. These reports incorporate advances in data and analytical methods and collectively represent the best and most relevant scientific information available for the Custer Gallatin NF.

Potential carbon effects are discussed qualitatively, with supporting estimates where possible. This is accomplished by drawing on the quantitative analysis of the impacts of past management activities on forest carbon stocks and fluxes, as well as through future-looking analysis where available (see updated Carbon Assessment in project record for additional detail).

Analysis area

The spatial scale of this analysis includes the forested lands of the Custer Gallatin NF. Based on FIA data, the Forest consists of approximately 2.5 million acres of forest land. The effects analysis for GHG emissions is the global atmosphere given the mix of atmospheric gases can have no bounds. The temporal scale for analyzing carbon stocks and emissions focuses on the expected lifespan of the plan. This report includes analysis and discussion beyond this expected lifespan to provide context for potential forest carbon dynamics and factors influencing these dynamics in the future. However, estimates of future carbon stocks and their trajectory over time remain unclear because of uncertainty from the multiple interacting factors that influence carbon dynamics.

Notable changes between draft and final EIS

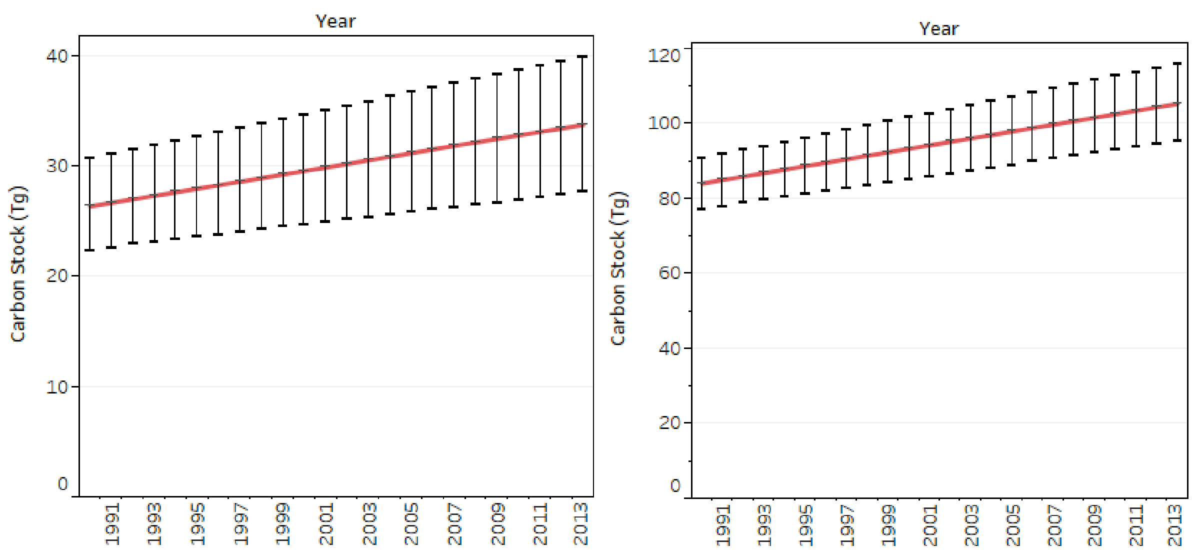
An updated baseline carbon assessment was conducted, utilizing new available tools from the USDA Forest Service Office of Sustainability and Climate, and is incorporated into project record of the FEIS. This analysis is updated based on that information, which draws upon many of the same data and literature sources described in the DEIS.

Affected Environment (Existing Condition)

Forests are dynamic systems that naturally undergo ebbs and flows in carbon storage and emissions as trees establish and grow, die with age or disturbances, and re-establish and regrow. Through photosynthesis, growing plants remove CO_2 from the atmosphere and store it in forest biomass, such as in plant stems, branches, foliage, and roots. Some of this organic material is eventually stored in forest soils through biotic and abiotic processes (Ryan *et al.,* 2010). Carbon can also be transferred and stored outside of the forest ecosystem in the form of wood products, further influencing the amount of carbon entering the atmosphere (Gustavvson *et al.,* 2006, Skog *et al.,* 2014).

Many management activities initially remove carbon from the forest ecosystem, but they can also result in long-term maintenance or increases in forest carbon uptake and storage by improving forest health and resilience to various types of stressors (McKinley *et al.,* 2011).

According to results of the Baseline Report (U.S. Department of Agriculture 2015), carbon stocks in the Custer NF increased from 26.3±4.2 teragrams of carbon (Tg C) in 1990 to 33.7±6.1 Tg C in 2013, a 22 percent increase in carbon stocks over this period (Fig. 1). On the Gallatin NF, carbon stocks increased from 83.9±6.9 Tg C in 1990 to 105.1±10.2 Tg C in 2013, a 20 percent increase. For context, the total 105.1 Tg C is equivalent to emissions from approximately 84 million passenger vehicles in a year. Despite some uncertainty in annual carbon stock estimates, reflected by the 95 percent confidence intervals, there is a high degree of certainty that carbon stocks on the Custer Gallatin NF have been stable or increased from 1990 to 2013 (Fig. 1).



Custer National Forest ***Gallatin National Forest***

Figure 1. *Total forest carbon stocks (Tg) from 1990 to 2013 for the CGNF, bounded by 95 percent confidence intervals. Estimated using the CCT model.*

Approximately 47 and 68 percent of the Custer and Gallatin NFs, respectively, are middle-aged and older (greater than 80 years), although there is also a strong representation of stands less than 20 years old due to recent wildfires (Fig. 9a). There is also a pulse of stands over 200 years old on the Gallatin NF. If the Forests continue on this aging trajectory, the pulse of middle-aged stands will reach a slower growth stage in coming years and decades (Fig. 9b), potentially causing the rate carbon accumulation to decline and the Forests may eventually transition to a steady state in the future. However, the pulse of young stands will also be moving into a maximum productivity stage, which may offset the declines in the middle-aged stands to a degree. In the middle aged stands, although yield curves indicate that biomass carbon stocks may be approaching maximum levels (Fig. 9b), ecosystem carbon stocks can continue to increase for many decades as dead organic matter and soil carbon stocks continue to accumulate (Luyssaert et al. 2008). Furthermore, while past and present aging trends can inform future conditions, the applicability may be limited, because potential changes in management activities and particularly disturbances could affect future stand age and forest growth rates (Davis et al. 2009, Keyser and Zarnoch 2012).

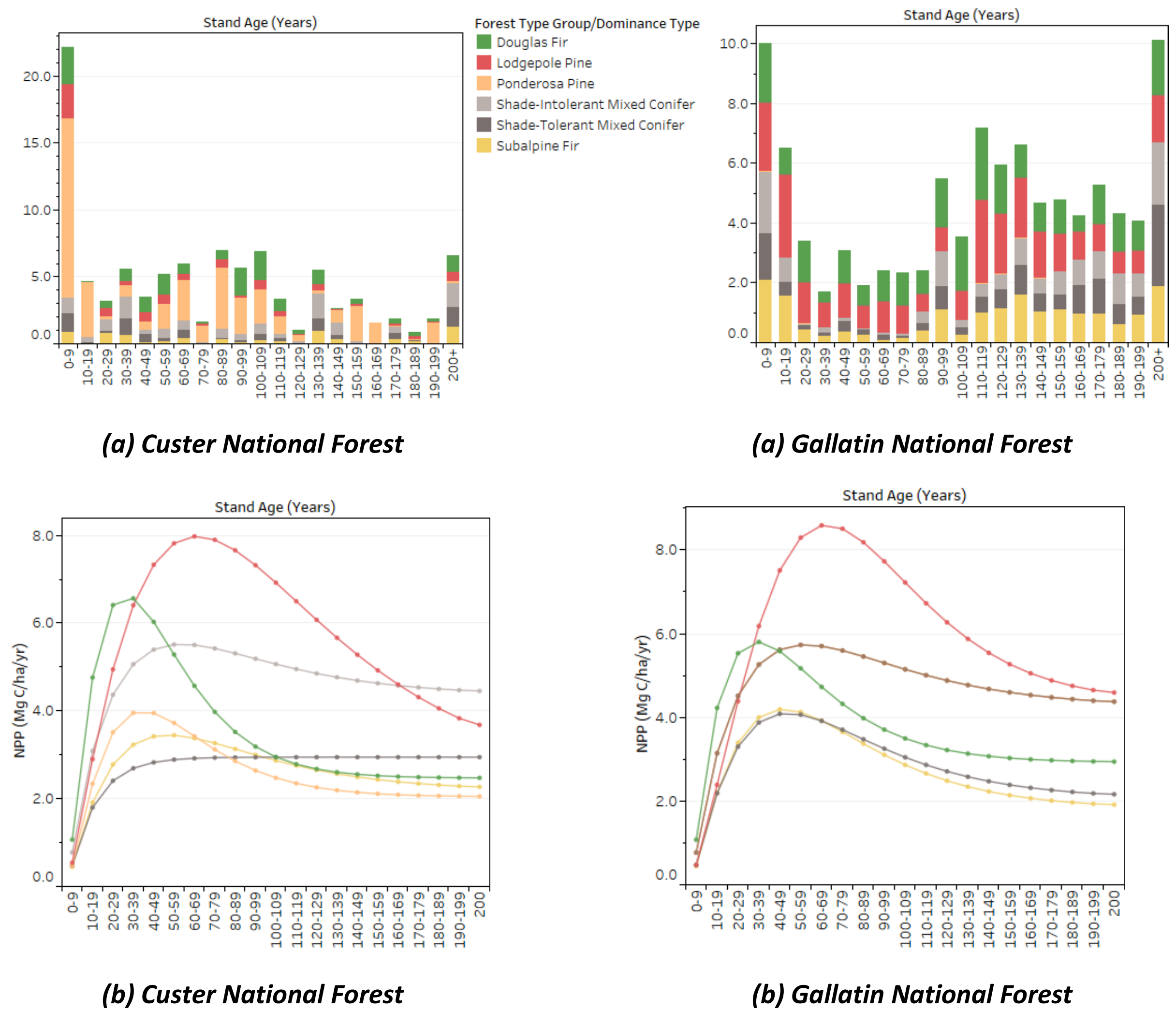
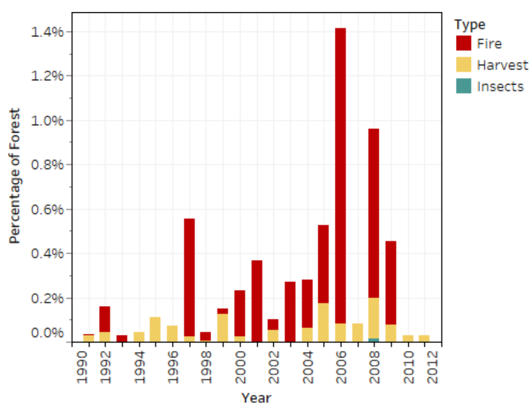
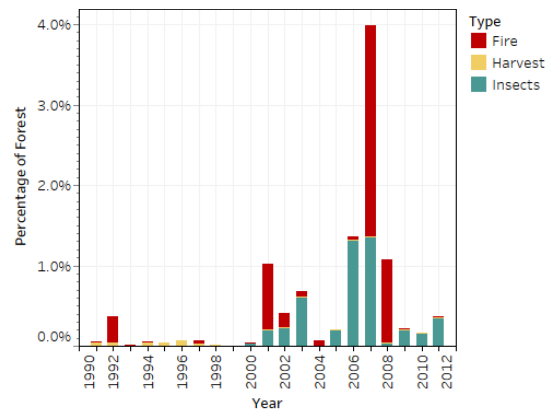


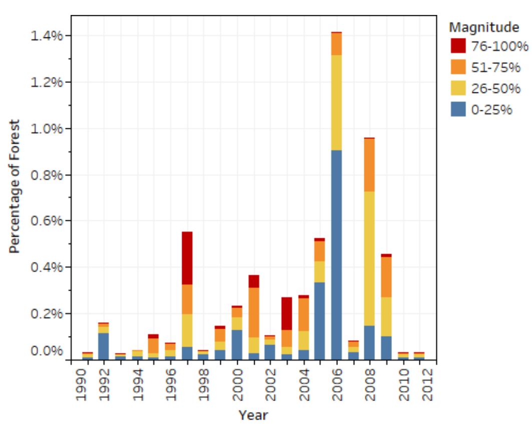
Figure 9. *(a) Stand age distribution in 2011 and (b) net primary productivity-stand age curves by forest type group in the Custer Gallatin National Forest. Derived from forest inventory data.*

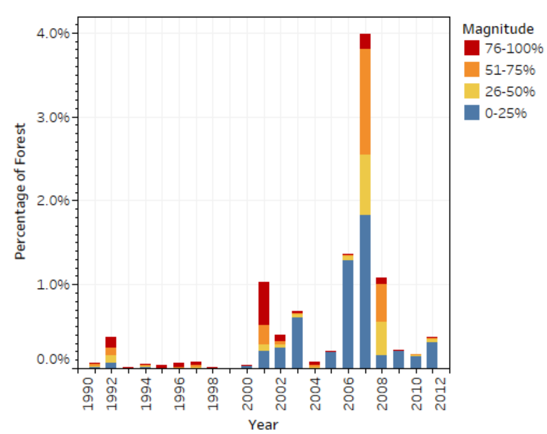
Wildfire and insects have been the dominant disturbance types detected on the CGNF from 1990 to 2011, in terms of the total percentage of forested area disturbed over the period (Fig. 6a). However, according to the satellite imagery, these disturbance agents affected a relatively small area of the forest during this time. In most years, wildfire affected less than 1 percent of the total forested area of either forest in any single year from 1990 to 2011. However in 2006, approximately 1.3 percent of the Custer NF burned, while in 2007 about 2.5 percent of the Gallatin NF experienced fire. On the Custer NF, wildfire in total affected less than 5 percent (approximately 13,250 ha) of the forested area during this period. Wildfire affected approximately 5.3 percent of the Gallatin NF from 1990 to 2011 (approximately 32,000 ha); and insects affected just under 5 percent (28,000 ha). Harvest also occurred on both forests but impacted less than 1 percent of either forest. Disturbance resulted in a range of canopy cover loss depending on disturbance type and year (Fig. 6b).





(a) Custer National Forest *(a) Gallatin National Forest*





(b) Custer National Forest *(b) Gallatin National Forest*

Figure 6. *Percentage of forest disturbed from 1990 to 2011 in Custer Gallatin National Forest by (a) disturbance type including fire, harvests, insects, and abiotic (wind), and (b) magnitude of disturbance (change in canopy cover). Estimated using annual disturbance maps derived from Landsat satellite imagery.*

The Custer Gallatin NF (Forest) contains approximately 170,000 hectares of non-forest lands. Grasslands, shrublands, and riparian and wetland areas cover most of these lands, accounting for approximately 14 percent of the total area on the Forest. The vast majority of the carbon in these non-forest systems, such as grasslands and shrublands, is stored belowground in soil and plant roots (McKinley and Blair 2008, Janowiak et al. 2017). By contrast, forests typically store roughly one-half of the total carbon belowground (Domke et al. 2017). Soils generally provide a stable ecosystem carbon pool relative to other ecosystem carbon pools.

Climate change introduces additional uncertainty about how forests—and forest carbon sequestration and storage—may change in the future. Climate change causes many direct alterations of the local environment, such as changes in temperature and precipitation, and it has indirect effects on a wide range of ecosystem processes (Vose et al. 2012). Further, disturbance rates are projected to increase with climate change (Vose et al. 2018), making it challenging to use past trends to project the effects of disturbance and aging on forest carbon dynamics.

Environmental Consequences

In a global atmospheric CO_2 context, even the maximum potential management levels described by the plan alternatives would have a negligible impact on national and global emissions and on forest carbon stocks, as described below. As in this case, when impacts on carbon emissions (and carbon stocks) are small, a quantitative analysis of carbon effects is not warranted and thus is not meaningful for a reasoned choice among plan alternatives (USDA Forest Service 2009). Although advances in research have helped to account for and document the relationship between GHG and global climate change, it remains difficult to reliably simulate observed temperature changes and distinguish between natural or human causes at smaller than continental scales (Intergovernmental Panel on Climate Change 2007).

Even more difficult is the ability to quantify potential carbon consequences of management alternatives in the future due to potential variability in future conditions and the stochastic nature of disturbances. The result of such uncertainty is often a very low signal-to-noise ratio: small differences in carbon impacts among management alternatives, coupled with high uncertainty in carbon stock estimates, make the detection of statistically meaningful differences among alternatives highly unlikely.

Management Direction under the Current Plans

The existing forest plans contain no plan components or direct acknowledgment related to carbon sequestration, or the use of management approaches to mitigate greenhouse gas emissions and climate change. Both existing plans contain direction aimed at promoting the sustainability of vegetation.

Management would continue similarly as in the recent past, resulting in a similar pattern of carbon storage and flux as discussed in the affected environment section. Direction in the current plans aimed at promoting the sustainability of vegetation could trend the Custer Gallatin towards greater resiliency, and thus enable the national forest to provide carbon sequestration over both the short and long term.

Management Direction under the Revised Plan Alternatives

All action alternatives provide the same desired conditions for terrestrial ecosystems and the standards and guidelines that help achieve or maintain those conditions. These plan components will help maintain critical ecosystem functions into the future, in part by balancing the maintenance of carbon stocks and rates of carbon uptake. The revised forest plan recognizes the important role of the forest related to carbon storage and sequestration, establishing a desired condition that directly addresses carbon sequestration (FW-DC-CARB-01). This desired condition applies to all revised plan alternatives and focuses on sustaining this key ecosystem service through maintenance or enhancement of ecosystem biodiversity and function and managing for resilient forests adapted to natural disturbance processes and changing climates. In addition, FW-GO-CARB-01 would promote cooperation and collaboration with interested partners in the development and implementation of research, management practices, and monitoring programs to better understand and address the effects of climate change on ecosystems and ecosystem services in order to inform adaptation and mitigation strategies.

Effects Common to all Alternatives

As required by planning regulations (USDA 2015c), the strategy for vegetation management on the Custer Gallatin National Forest under the revised plan alternatives is to provide for ecological integrity and resilience, supporting a diversity of plant and animal communities, and to provide for social and economic contributions to local communities. In response to this direction, all revised plan alternatives incorporate an ecologically based approach to vegetation management, including direction to manage for conditions that would occur under a natural disturbance regime, and be more resilient in the face of future uncertainties. The revised forest plan also explicitly recognizes the importance of the role of the Custer Gallatin related to carbon storage and sequestration, establishing a desired condition that directly addresses carbon sequestration (FW-DC-CARB-01). This desired condition focuses on sustaining this key ecosystem service through maintenance or enhancement of ecosystem biodiversity and function, and managing for resilient forests adapted to natural disturbance processes and changing climates. The full suite of ecological plan components is consistent with and support this desired condition. This approach to management of forests for purposes of contributing to climate change mitigation is supported by a number of scientific sources (Ruddell et al. 2006, Hurteau et al. 2008, Reinhardt and Holsinger 2010, Ryan et al. 2010b, Wiedinmyer and Hurteau 2010, North and Hurteau 2011, Schaedel et al. 2017). The forest plan direction in the revised plan alternatives provide more clarity and stronger integration of ecological concepts and management for resilient forest conditions than current plans.

In general, management activities (such as timber harvest) would initially directly reduce carbon stocks on the forest, though minimally. However, this initial effect would be mitigated or even reversed with time, reducing the potential for negative indirect and cumulative effects. These short-term losses and emissions are small relative to both the total carbon stocks on the forest and national and global emissions. Further, the proposed activities would generally maintain and improve forest health and supply wood for forest products, thus having positive indirect effects on carbon storage. The Custer Gallatin NF will continue to be managed to maintain forests as forests and the many ecosystem services and co-benefits the forests provide, including carbon uptake and storage. The following management strategies are available under all alternatives and also influence carbon uptake and storage potential:

- Manage the forest to provide a mosaic of forest structure and composition that is consistent with the natural range of variability to support ecological integrity, resilient ecosystems and provide wildlife habitat. Managing for younger stands where appropriate may cause a decline in carbon stocks in the short term, but compared with older stands, doing so promotes relatively high rates of carbon uptake over time as forests regrow (Pregitzer and Euskirchen 2004).
- Preserve, enhance or accelerate the development of large trees stands and structures and maintain or increase old-growth conditions to support higher carbon stocks in mature forests compared with younger stands (Harmon et al. 1990).
- Decrease forest densities and fuel conditions to reduce the risk of large, stand-replacing disturbance from insect, disease, and fire. Although this strategy initially reduces carbon stocks, it can lower risk for greater carbon stock losses and emissions in the future (Wiedinmyer and Hurteau 2010).
- Ensure successful reforestation after harvest or mortality-inducing disturbances to ensure continued carbon uptake and storage (Intergovernment Panel on Climate Change 2014).
- Promote desired composition, structure, function, and pattern (ecological integrity) which will support long-term carbon uptake and storage in the face of changing environmental conditions (Millar et al. 2007).
- Use harvested wood for valuable and renewable products to store carbon over the long-term and substitute for energy-intensive materials or fuels, reducing the net carbon emissions into the atmosphere (Gustavsson et al. 2006, Lippke et al. 2011).

Each of the alternatives include a similar number of acres to be treated, thus they are projected to have similar effects on carbon. Plan direction in all alternatives would support the CGNF towards continued resilience at both the stand and landscape scales. Alternative F is the preferred alternative, and therefore is evaluated here as an indicator of the level of influence of the alternatives on carbon dynamics. Refer to the terrestrial vegetation and timber analyses for full discussions of projected treatment areas under each action alternative.

The estimated treatment area for harvests and thinning under alternative F would average approximately 1,000 acres per year or about 0.04 percent of total forested area on the CGNF. This is similar to the no-action alternative, and a 150% from the average annual harvest levels recorded from 1990-2011 based on the Landsat satellite imagery.

Assuming that the annual carbon impact also increases up to 1.5 times above past levels, harvest treatments under alternative F may result in a maximum removal of about 30,000 Mg of carbon per year from aboveground pools. Alternative F also includes prescribed burning on an average of about 3,000 acres annually. Wildfires generally burn at higher severities and result in greater carbon losses than prescribed burns. By reducing hazardous fuels, prescribed burning may indirectly reduce the risk of more severe wildfires and greater carbon losses in the future (Agee and Skinner 2005, Wiedinmyer and Hurteau 2010).

Considering the maximum area treated with harvesting and prescribed fire, the amount of carbon that might be removed is small relative to the approximately 110 million metric tonnes (Tg) of carbon stored in the forest ecosystem of Custer Gallatin NF. With maximum intensification, potential management actions would affect up to less than 0.25 percent of the forested area and much less than 1 Tg C annually. The alternatives will not significantly, adversely, or permanently affect forest carbon storage, but would rather achieve a more resilient forest condition that will improve the ability of the Custer Gallatin NF to maintain carbon stocks and enhance carbon uptake.

Consequences to Carbon Storage and Sequestration from forest Plan Components associated with Other Resource Programs or Management Activities

Effects from Terrestrial Vegetation Management

Under all revised plan alternatives, plan components for terrestrial vegetation would make sure forested and non-forested plant communities are managed to be resilient (e.g. FW-DC-VEGF-(01-09) and FW-DC-VEGNF-(01-04)) , therefore ensuring that the carbon sequestration capacity is maintained over the long term on the Custer Gallatin National Forest. The current plans do not prescribe desired conditions based on the natural range of variation but would also result in the lands of the Custer Gallatin National Forest being managed for native vegetation communities and therefore would provide a similar potential for carbon sequestration.

Effects from Fire and Fuels Management

Fire, (both natural and human ignitions) pose the greatest potential for short-term reductions in carbon sequestration by removing vegetation as well as causing carbon emissions. However, fire is also a primary mechanism for restoring and maintaining native vegetation with conditions consistent with the natural range of variation, thereby contributing to carbon sequestration potential over the long term. Plan components for fire and fuels management would help make sure the long-term sustainability of vegetation communities while also allowing for flexibility in allowing fire to play its natural role on the landscape (FW-DC-FIRE-01, FW-DC-FIRE-02). These factors would generally be the same for all alternatives.

Effects from Timber Management

Plan components for timber management would allow for the short-term, localized reduction of carbon sequestration through the removal of living vegetation. The magnitude of this is greatest in alternative E and least in alternative D, but the difference between alternatives relative to effects on carbon is negligible. However, plan components that guide timber management, including desired vegetation conditions (FW-DC-TIM-03) and forested vegetation management objectives (FW-OBJ-VEGF-01), would make sure that forest resiliency is promoted by these activities; therefore, timber management would contribute to the long-term capacity of forests to sequester carbon.

Effects from Permitted Livestock Grazing

In all alternatives, livestock grazing would occur on the Custer Gallatin National Forest. Plan components would make sure that grazing is managed in a manner that would maintain desirable vegetation communities (FW-STD-GRAZ-01), and therefore would not preclude the carbon sequestration potential of rangelands under any alternative.

Effects from Watershed, Soil, Riparian, and Aquatic Management

Measures to protect aquatic habitat, riparian management zones, and watersheds would generally result in vegetation being maintained as needed for watershed function and would result in a greater likelihood of vegetation cover being maintained within riparian management zones (e.g. FW-DC-RMZ-01, FW-STD-RMZ-01, FW-STD-RMZ-02). These measures would be greater for the revised plan alternatives than the current plans. The retention of vegetation in riparian areas would provide areas of refugia (potential old growth), and seed sources to contribute to the larger resilience (and therefore carbon sequestration potential) of vegetation on the landscape over time.

Cumulative effects

Climate change is a global phenomenon, because major greenhouse gases mix well throughout the planet’s lower atmosphere. Estimated emissions of GHGs in 2010 were 13,336 ± 1,227 teragrams carbon globally (Intergovernment Panel on Climate Change 2014) and 1,881 teragrams carbon nationally (US EPA 2015). All of the plan alternatives are projected to contribute negligibly to overall GHG emissions. Furthermore, it is difficult and highly uncertain to ascertain the indirect effects of emission from multiple, generally small projects that make up these alternatives on global climate. Management actions are directed at a very small percentage of the total forest land on the CGNF; even in the near-term, these alternatives would have a minimal direct effects on carbon emissions and carbon stocks relative to total carbon stocks in the CGNF. Because the potential direct and indirect effects of alternatives would be negligible, the contribution of the plan’s proposed actions to cumulative effects on global atmospheric GHG concentrations and climate change would also be negligible.

Conclusions

A large body of science agrees that future climate conditions will include increasing average annual temperatures over the coming decades, which will have impacts to natural resources.

Plan components in the action alternatives are designed to provide for ecological integrity and resiliency to disturbances. Potential negative effects may be mitigated and completely reversed with time as the forests regrow. Over the longer term, the activities allowed by the forest plan are likely to increase carbon storage and reduce emissions, by reducing disturbance risk and storing carbon in wood products. The management mechanisms applied in all plan alternatives are consistent with internationally recognized climate change adaptation and mitigation practices identified by the IPCC (Intergovernment Panel on Climate Change (IPCC) 2007).

Carbon stocks on the CGNF would likely continue to increase or remain stable under all plan alternatives in the foreseeable future. Natural ecosystem processes, including forest growth (succession) and small-scale disturbances (e.g., fire, insects, harvests) would continue to influence carbon stocks and emissions, but they are not expected to substantially change current trends in carbon over the span of the plan. All plan alternatives would preserve existing forest lands and forests by improving forest conditions and retaining forest characteristics by maintaining current land use. Given the likely changes in land use in coming decades on adjacent land ownerships, this is a critical goal.

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