Baseline Estimates of Carbon Stocks in Forests and Harvested Wood Products for National Forest System Units

Intermountain Region

Climate Change Advisor's Office
Office of the Chief

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Preface

Our forests – national forests as well as private and other public forests – provide an important ecosystem service in the form of carbon sequestration – the uptake and storage of carbon in forests and wood products. This service is becoming more valuable as the impacts of greenhouse gas emissions are becoming more fully understood and experienced. The Forest Service has always led efforts to practice, develop, and demonstrate sound and sustainable management of forest-based resources; the management of forest carbon is no exception. As stated in the Forest Service National Roadmap for Responding to Climate Change: “Managing America’s forests and grasslands to adapt to changing climates will help ensure that they continue to produce the benefits that Americans need, while helping to mitigate the effects of a changing climate and to compensate for fossil fuel emissions through carbon storage in healthy forests.” The Roadmap further states that “Forest management activities will play a critical role in ensuring that forests remain a net carbon sink.”

The material in this report was produced for each of the national forests to help us better understand the carbon resource we manage and to inform our decision making and partnership efforts with baseline data about the condition and trend of carbon component of the resource base. With this information we can develop our capacity to integrate carbon into our planning and decision making and create a greater awareness of how carbon sequestration goals can be combined with goals for other resources and ecosystem services. We will update these numbers periodically.

The Forest Service has a strong basis for leading the national conversation and action on forest carbon. We know how trees and forests grow and how they are impacted by stressors and disturbances, and we are constantly learning more. Now we must translate that knowledge into carbon outcomes and options and develop a refined, science-based awareness of new and unfolding knowledge about carbon cycles and pattern changes. We need to maintain a robust monitoring, analysis, and reporting system to keep ourselves and the public informed about the status and trends at scales ranging from national to state to individual forests and grasslands. We will need some new knowledge about the effects of forest and grassland management on the dynamics of carbon in different systems and about how the carbon cycle, the water cycle, and other ecosystem benefit patterns intersect. And we will need to rapidly soak up the emerging information about how forest and grassland carbon storage is being influenced by the changing climate itself. Our Research and Development division has much of the information needed and is at work on many of these unanswered questions.

We have a positive story to tell. Forest and grassland management makes good sense through the lens of carbon storage. But we have not fully clarified or featured their carbon storage impacts and benefits. Keeping forests as forests is one of the most cost-effective carbon storage measures. Restoration, getting badly disturbed forests and grasslands back to producing a full range of environmental services, is another. Ensuring rapid regeneration after disturbance is especially important for retaining carbon in the forest landscape. Maintaining forest health through appropriate fire, insect, disease, and invasive species management also has strong carbon storage and protection benefits. Understanding the consequences of harvesting, thinning, and other vegetation management practices on forest carbon cycles will become more important as we evaluate options. Even though practices such as thinning and prescribed fire may release carbon in the short term, they focus growth and storage for the future on trees that are at lower risk and/or more resilient to disturbance. Appropriate forest management and protection can substitute lighter, strategically placed, and more recoverable emissions for disturbance emissions that would be more severe, extensive, and less reversible. It's risk management on a large scale, and forest and grassland managers are, among other roles, the risk managers for ecosystems.

Managing carbon in a forest is not the same as managing the forest for carbon. Carbon management is one part of sustainable land management. Our job is to maintain the long-term health of forests and grasslands and all of their benefits – the ones on which we have traditionally focused as well as those whose importance may not have been as well recognized. Carbon adds another dimension to our work, and requires a different perspective on basic principles. There may be tradeoffs between carbon and other services, but dealing with tradeoffs and creating new synergies has always been part of our resource management mission.

Forest ecosystems are more complex than we think – let's not forget that. And take care of them so they can keep on taking care of us. We hope that the information contained here will help us create an even deeper and more refined appreciation for forest carbon and provide a stronger foundation for designing management strategies that incorporate care for the carbon resource.

Dave Cleaves, Former Climate Change Advisor to the Chief

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1.0 Introduction

Human activities such as fuel burning, industrial activities, land-use change, animal husbandry, and fertilized and irrigated agriculture have led to increases in ambient greenhouse gases (GHGs), including carbon dioxide, methane, and nitrous oxide. Global atmospheric concentrations of GHGs have increased markedly as a result of human activities since 1750 and now greatly exceed pre-industrial values (IPCC 2007). GHGs contribute to the "greenhouse effect" and are causing the surface temperature of the Earth to increase with a number of associated large scale changes (NCA 2014).

The Forest Service recognizes the vital role that our nation's forests and grasslands play in carbon sequestration. Carbon sequestration by forests is one way to mitigate GHG emissions by offsetting losses through removal and storage of carbon. Carbon dioxide uptake by forests in the conterminous United States offset approximately 16 percent of our national total carbon dioxide emissions in 2011 (US EPA 2013). Forests and other ecosystems generally act as carbon sinks because, through photosynthesis, growing plants remove carbon dioxide from the atmosphere and store it.

Recent estimates of net annual storage indicate forests are an important carbon sink, removing more carbon from the atmosphere than they are emitting (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). Western forest ecosystems may also emit greater amounts of carbon if wildfire area and insect disturbance increase as expected (Vose et al. 2012).

The National Forest System (NFS) constitutes one-fifth (22 percent) of the Nation's total forest land area and contains one-fourth (24 percent) of the total carbon stored in all U.S. forests, excluding interior Alaska. Thus, management of these lands and disturbance impacts influence carbon sequestration and storage and mitigation of GHG emissions. The future trajectory of carbon stocks on the national forests will be influenced by the variability of conditions and disturbance regimes such as wildfire, insect outbreak, and extreme weather across the U.S.

Rates of net carbon sequestration in forests may be enhanced through management strategies that retain and protect forest land from conversion to nonforest uses, restore and maintain resilient forests that are better adapted to a changing climate and other stressors, and reforest lands disturbed by catastrophic wildfires and other natural events (e.g., mortality following windthrow).

Harvested wood is of additional importance when considering carbon benefits from forests. Forest restoration and other treatments that generate long-lived wood products, such as lumber and furniture, transfer ecosystem carbon to the Harvested Wood Products pool (HWP) where carbon remains stored and not contributing to net GHG emissions. Substitution of wood for more fossil fuel-intensive building materials, such as concrete, steel, or plastic, has a carbon emissions benefit. Forest vegetation treatments also generate excess material (woody biomass) which, if utilized, can be a renewable energy substitute for fossil fuels. Carbon management is, therefore, an increasingly important consideration in NFS management.

A nationally consistent carbon assessment framework has been developed for the NFS to deliver mid- to broad level forest carbon information for every region and individual national forest. This report is the first component of that framework and builds upon the foundation established in an earlier report (Heath et al. 2011).

2.0 Purpose of This Report

This report provides baseline carbon stocks and trends (for the time period 2005 to 2013) for seven different forest ecosystem[1] carbon pools – above-ground live tree, below-ground live tree, standing dead, understory, down dead wood, forest floor and soil organic carbon – and also provides estimates of carbon stored in HWP over longer time periods depending upon data availability. These estimates are for forestland on national forest land.

Carbon stock and trend information, in conjunction with companion assessments on forest carbon disturbances *(currently being developed)* will help inform forest managers and the public of the relationship between carbon storage and past management and disturbance impacts and to begin considering the short and long-term carbon consequences of alternative forest management strategies. Changes in carbon stocks and resulting net emissions may be influenced through vegetation management strategies. Land management and restoration strategies, plans, and actions, such as fire and fuels management, timber harvesting, reforestation, and other forest stand treatments, can be designed to integrate carbon sequestration capacity across broad landscapes and over the long-term, while meeting other resource management objectives. Wood uses for products can also complement land management by extending the storage of carbon in useful products and reducing emissions as wood products substitute for those that emit more CO_2 and other greenhouse gasses. These considerations are important components of sustainable forest management.

Existing guidelines for considering forest carbon are found in various Forest Service policies, programs, and activities such as the 2012 Planning Rule and directives, the Climate Change Roadmap/Scorecard, other internal guidance for planning and project-level decisions, and in several State & Private Forestry programs.

The information in this and ensuing carbon assessment reports directly support NFS units in making measurable progress on Climate Change Performance Scorecard Element 9 (Carbon Assessment and Stewardship), while helping forests meet carbon assessment requirements of the 2012 Planning Rule and directives.

Scorecard Element 9 poses the following questions:

> ***Does the Unit have a baseline assessment of carbon stocks and an assessment of the influence of disturbance and management activities on these stocks? Is the Unit integrating carbon stewardship with the management of other benefits being provided by the Unit?***

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[1] *Forest ecosystem* is used interchangeably with *forest land,* as per the Forest Inventory and Analysis definition. See Glossary.

This report and associated data are designed to meet the intent of the baseline assessment of carbon stocks. The assessment of the influence of disturbance and management activities will be addressed through companion assessments currently being developed for each region and individual national forest which will become available over the next 2-3 years. Units are encouraged to use other means to obtain this information if the timeline will not meet their needs.

Armed with these two pieces of information -- carbon stocks and the influences on those stocks -- the unit should then be able to begin to consider forest carbon trends and apply that knowledge in its land management assessment, planning and implementation. This leads to the second Element 9 question -- Is the Unit integrating carbon stewardship with the management of other benefits being provided by the Unit? This requirement could be accomplished through various means, such as through the land management planning process or other strategic program planning (see the **Forest Carbon Principles** table below). Units are encouraged to review the Scorecard Guidance, including Scorecard Appendix F.

Units can apply this data in their forest management planning and practices by asking questions such as, but not limited to –

- How is the land management plan area playing a role in sequestering and storing carbon?
- How have disturbances, projects, and activities influenced carbon stocks in the past and may affect them in the future?
- Are existing conditions and trends of forest vegetation (aboveground carbon pool) indicating the plan area is a carbon sink or carbon source?
- Under existing plan guidance, what is the future trend of the plan area in sequestering and storing carbon?
- Are there opportunities to change plan components to influence these trends?

Neither the scope of the Carbon Assessment Framework nor of this baseline assessment includes 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 GHG inventory for business operations is included in the FY12 Sustainable Operations Collective Accomplishment Report. USDA’s 2013 Sustainability/Energy Scorecard, which includes information on GHG emissions reporting, is available here.

These baseline estimates are produced following methods described in Healey, Birdsey, Woodall and others (in prep). This General Technical Report will summarize details from the peer-reviewed literature and will be published by the Rocky Mountain Research Station in 2015.

What Does Paris and National Forest Carbon Have in Common?

There are always uncertainties when it comes to estimating forest carbon namely in that we don't directly measure carbon atoms across the landscape. To estimate forest carbon, we must constantly identify the best data sources and models while keeping an eye to emerging science and inventories. We know that the use of forest inventories from over 20 years ago is not optimal for creating contemporary baselines of forest carbon. This will be evident as you assess the carbon baselines and associated uncertainties within this whitepaper. Alleviating this issue is a paramount task for FS Research &Development in the year ahead.

We are embarking on an overhaul of the national greenhouse gas inventory to meet the data needs at the national scale for future greenhouse gas commitments the US may make at the upcoming Paris climate negotiations. One large task will be to reduce the reliance on the older, periodic inventories that introduce great uncertainty into carbon baseline assessments. Although the road to Paris is lined with improvements to our national carbon baselines as requested by the White House Council on Environmental Quality, there will be opportunities to engage the National Forest System so that everyone can benefit from the future of refined carbon assessments. Please read this report, confirm our acknowledged sources of uncertainty, and engage us on the next round of improvements upon the heels of the Paris climate negotiations. Carbon is a unifying element of forest ecology…can it also unify our approach to forest monitoring across scales?

Forest Carbon Principles

Forest carbon management (carbon stewardship) may best be articulated through the following principles and guidelines. They are intended to provide considerations for integrating carbon management with planning and implementation processes and with efforts to adapt forests to the impacts of a changing climate. These are preliminary guiding principles intended to be refined, updated and formally approved based on field experience, emerging science and higher level policy revisions and interpretation across the full range of Forest Service programs and authorities, not just NFS.

1. **Emphasize ecosystem function and resilience.** Carbon sequestration capacity depends on sustaining and enhancing ecosystem function to maintain resilient forests adapted to changing climate and other conditions.
2. **Recognize carbon sequestration as one of many ecosystem services.** Carbon sequestration is one of many benefits provided by forests, grasslands, and forest products, now and in the future. Carbon sequestration should be considered in context with other ecosystem services.
3. **Support diversity of approaches in carbon exchange and markets.** Recognize that decisions about carbon in America's forests are influenced by ownership goals, policy, ecology, geography, socioeconomic concerns, and other factors that vary widely.
4. **Consider system dynamics and scale in decision making.** Evaluate carbon sequestration and cycling at landscape scales over long time frames. Explicitly consider uncertainties and assumptions in evaluating carbon sequestration consequences of forest and grassland management options.
5. **Use the best information and methods to make decisions about carbon management.** Base forest management and policy decisions on the best available science-based knowledge and information about system response and carbon cycling in forests, grasslands, and wood products. Use this information wisely by dealing directly with uncertainties, risks, opportunities, and tradeoffs through sound and transparent risk management practices.
6. **Strive for program integration and balance.** Carbon management is part of a balanced and comprehensive program of sustainable forest management and climate change response. As such, forest carbon strategies have ecological, economic, and social implications and interactions with other Forest Service programs and strategies, such as those for energy and water.

Note: These principles are not meant to imply that maximizing forest carbon storage should be the objective of any forest plan or that carbon should be the most important or overriding purpose of forest plans or project actions. This information is provided to help forests and their stakeholders determine the state of the carbon resource, and how carbon stewardship might be blended with other ecosystem service goals in planning and management.

These reports are a path forward for carbon literacy on national forests. They provide a basic overall assessment of where carbon is stored at mid to broad scales (i.e., forest and region). They provide basic information for those forests that may lack more detailed data or expertise on carbon. They are not meant to be used directly in project-level decision making, except to provide broad context in which to reflect how management actions might contribute to overall carbon sequestration trends and patterns. The disaggregation of the National Greenhouse Gas Inventory comes with uncertainty (*further explained in Section 4*), especially in modelled pools such as soils and forest floor. This is where local expertise or datasets can supplant these general baselines.

3.0 Regional Description – Intermountain Region

The Intermountain Region is spread across six states and about 22.6 million acres of these NFS lands are classified as forest land (Figure 1, 2).[2] Included are 13 national forest units located within the perimeter of Utah, Idaho, Wyoming, Colorado, California and Nevada. These units include the Ashley, Boise, Bridger-Teton, Dixie, Fishlake, Manti-La Sal, Payette, Salmon-Challis, Sawtooth, Caribou-Targhee, Humboldt-Toiyabe, and Uinta-Wasatch-Cache National Forests and the Desert Range Experiment Station.

Total forest land (millions of acres) in the Intermountain Region increased from 2005 to 2013 (Figure 2, differences are well within error bounds indicating no significant change).

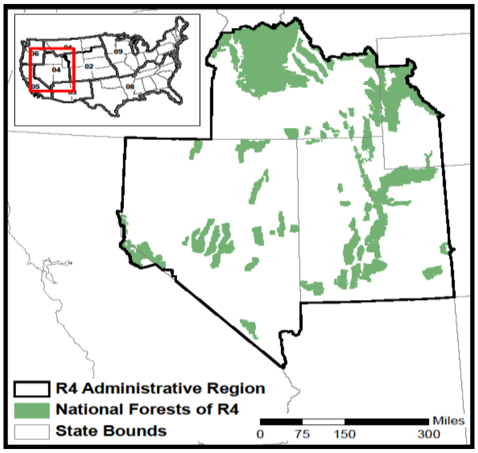

Figure 1. Map of the Intermountain Region (also known as R4).

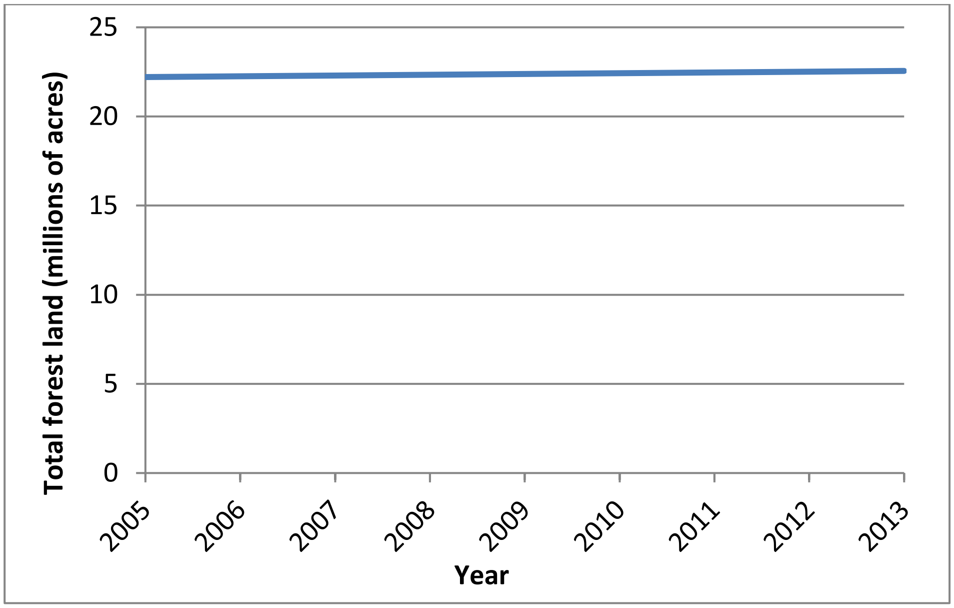

Figure 2. Total forest land (millions of acres) in national forests in the Intermountain Region from 2005 to 2013.

4.0 Methodology, Uncertainty and Results

4.1 Ecosystem Carbon Stocks

4.1.1 Methodology

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[2] Forest land is defined as a land-use category that includes areas at least 36.6 m (120 feet) wide and 0.4 ha (1 acre) in size with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. For expanded definition, see glossary.

Estimates of forest carbon stocks are based on forest inventory data obtained from the Forest Service, Forest Inventory and Analysis (FIA) program as it is the only consistent dataset across all ownerships and forests of the US. The Carbon Calculation Tool (CCT) estimates carbon stocks based on data from two or more forest surveys conducted at each NFS unit using FIA data (Smith, Heath & Nichols 2010). For each national forest, carbon stocks are calculated separately within each state or sub-state division based on available inventories (Woodall et al. 2013). As the National Greenhouse Gas Inventory (NGHGI) of forests is focused on forest land use, grasslands were only included in the inventory if they contained significant forest land.

Carbon Units

The following table provides a crosswalk among various measurement units used for the inventory, monitoring, and assessment of carbon across multiple sectors within the U.S., worldwide, and in this report.

Tonnes			**Grams**		
Multiple	**Name**	**Symbol**	**Multiple**	**Name**	**Symbol**
			10^0	gram	G
			10^3	kilogram	Kg
10^0	tonne	t	10^6	megagram	Mg
10^3	kilotonne	kt	10^9	gigagram	Gg
10^6	megatonne	Mt	10^{12}	teragram	Tg
10^9	gigatonne	Gt	10^{15}	petagram	Pg
10^{12}	teratonne	Tt	10^{18}	exagram	Eg
10^{15}	petatonne	Pt	10^{21}	zettagram	Zg
10^{18}	exatonne	Et	10^{24}	yottagram	Yg

1 hectare (ha) = 0.01 km2 = 2.471 acres = 0.00386 mi2

CCT is the official reporting tool for interpreting historical FIA data to develop timelines of carbon stock estimates. It is currently the best nationally available integration of historical and current designs to identify trends in carbon storage. Despite unavoidable uncertainties related to changes in FIA, CCT-based assessments of NFS carbon stocks represent an objective application of a national carbon accounting system.

Carbon stocks are estimated by linear interpolation between survey years for the seven ecosystem carbon pools – above-ground live tree, below-ground live tree, understory, standing dead trees, down dead wood, forest floor, and soil organic carbon – in each NFS administrative unit within each state/sub-state in each year. These seven pools are defined and calculated as follows –

- 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 (CRM) 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.

- Below ground live-tree carbon is based on the differences between whole trees and above ground only.

- 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 CRM method applied to live trees (Woodall et al. 2011) with modifications to account for decay and structural loss.

- Understory includes all live herbaceous vegetation and woody vegetation up to 1 inch d.b.h. 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).

  $$\text{Ratio} = e^{(A - B \times \ln(\text{live tree C density})}$$

  In this equation, "ratio" is the ratio of understory C 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.

- 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.

- 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) describe processes for decay or loss of forest floor following harvest and the net accumulation of new forest floor material following stand growth.

- Soil organic carbon includes all organic material in soil to a depth of 1 m 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).

Reliable estimates of forest carbon across the diverse forests of the United States require a high level of investment in both annual monitoring and associated analytical techniques. Development of improved monitoring/reporting techniques is a continuous process that occurs simultaneously with annual NGHGI submissions (US EPA 2014). Only when forest carbon monitoring techniques are thoroughly vetted are they adopted as part of the NGHGI (Woodall 2012). Research is underway to use a national inventory of forest floor carbon stocks (Domke et al. In Review) to refine the modeling of this pool. Initial results from this work suggest that the NGHGI model may be overestimating forest floor carbon. Once this research is peer-reviewed, efforts will be made to incorporate the improved models into the NGHGI and hence subsequent national forest baselines. Subsequent to this research initiative, refinements are planned in regard to the pools of soil organic carbon, belowground biomass, understory vegetation, and woodland-versus-forest delineations.

4.1.2 Uncertainty

Uncertainty analyses of ecosystem carbon stocks and stock change estimates at the national-scale are conducted using Monte Carlo simulations in an effort to ascertain total uncertainty. The uncertainty of forest carbon stock change at the national-scale often ranges between 20-30%, suggesting that uncertainty simulations at scales far smaller (e.g., individual national forests) than the Nation should greatly exceed 30% (e.g., >100% for individual pools in individual forests).

Some sources of uncertainty with the FIA data include sampling error (our area estimates are based on our network of plots and not a census), measurement error (species identification errors), and model error (associated with tree volume models and carbon pool estimates, interpolation models between different sample designs). We also lack some temporal sensitivity because the inventory of plots is being implemented on a re-measurement cycle that lasts from 5 to 10 years, depending on geographic region. Forests in the Western United States have more uncertainty in their carbon data because of the 10 year measuring cycle.

Appendix A displays total forest ecosystem carbon stocks and carbon stock change data with uncertainty values for each NFS unit from 2005 to 2013. A detailed description of the methodology used to derive uncertainty values can be found there.

Although current levels of uncertainty are high – with ongoing research geared towards reducing these uncertainties – this should not exclude local managers from using these initial carbon baselines to engage in learning more about forest carbon.

4.1.3 Results

Total forest ecosystem carbon (in all seven pools) stored in the Intermountain Region increased between 2005 and 2013, with 1069 Tg in 2005 and reaching 1084 Tg in 2013 (Figure 3). Figure 4 displays these trends for each of the national forests between the years 2005 and 2013, where the Salmon-Challis National Forest (NF) stored the largest amount of carbon in the region, approximately 164 Tg in 2005 and 166 Tg in 2013. During this period, the Ashley, Bridger-Teton, Fishlake, Manti-La Sal, Payette, Caribou-Targhee, Humboldt-Toiyabe, and Uinta-Wasatch-Cache National Forests generally increased in total forest ecosystem carbon, while the Boise, Dixie, and Sawtooth National Forests generally decreased. Total forest ecosystem carbon in the Desert Range Experiment Station stayed the same throughout this period.

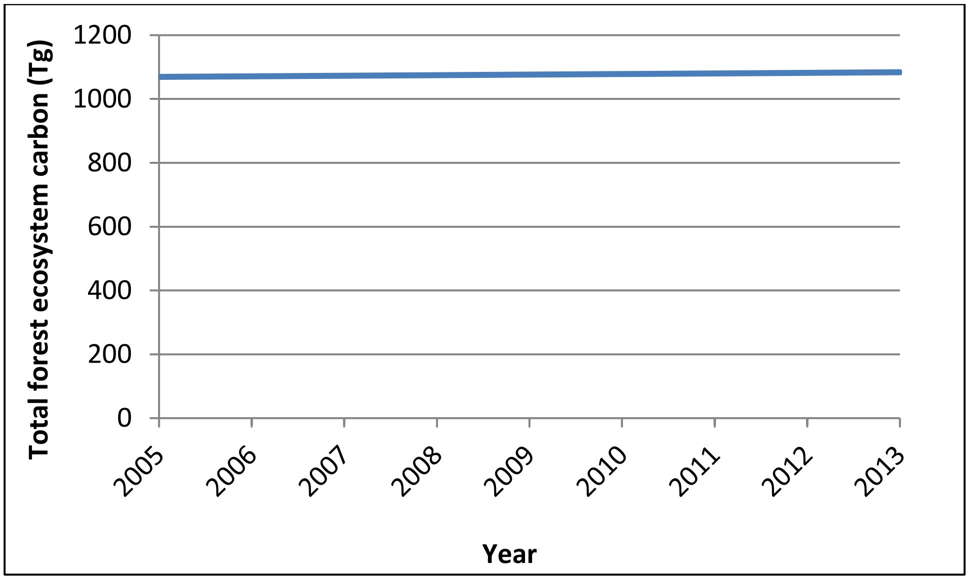

Figure 3. Total forest ecosystem carbon (Tg) for the Intermountain Region from 2005 to 2013.

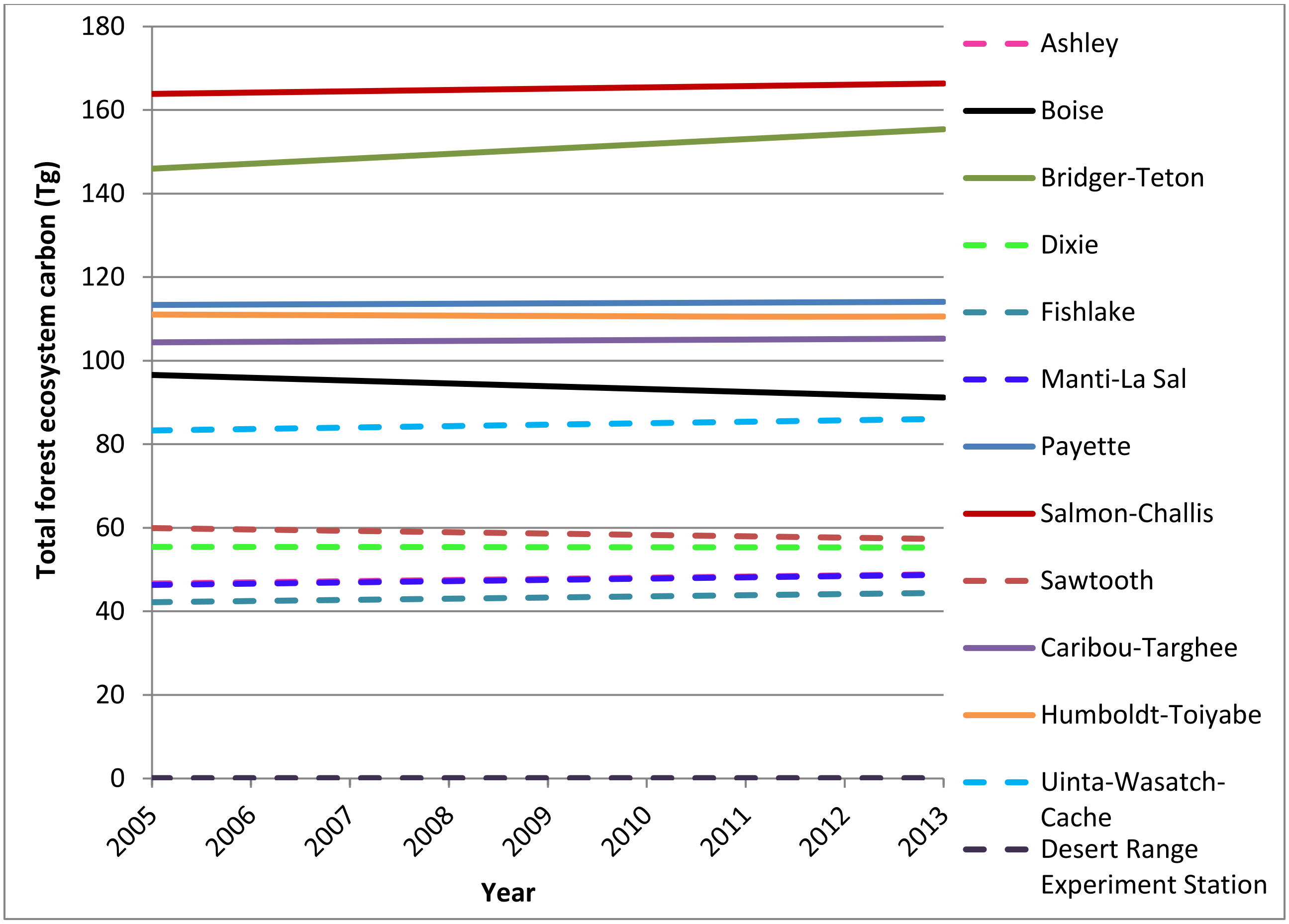

Figure 4. Total forest ecosystem carbon (Tg) for the national forests in the Intermountain Region from 2005 to 2013.

Region wide, the amount of carbon (Tg) stored in the understory, standing dead, down dead, forest floor and soil organic carbon pools increased between 2005 and 2013, while it decreased in the above-ground and below-ground pools as shown in Figure 5. Between the two years, the highest percent change in carbon storage occurred in the standing dead pool, (a 7% increase), and the lowest in the forest floor pool, (a 0.9% increase). As of 2013, most of the carbon is concentrated in the above-ground, forest floor and soil organic carbon pool.

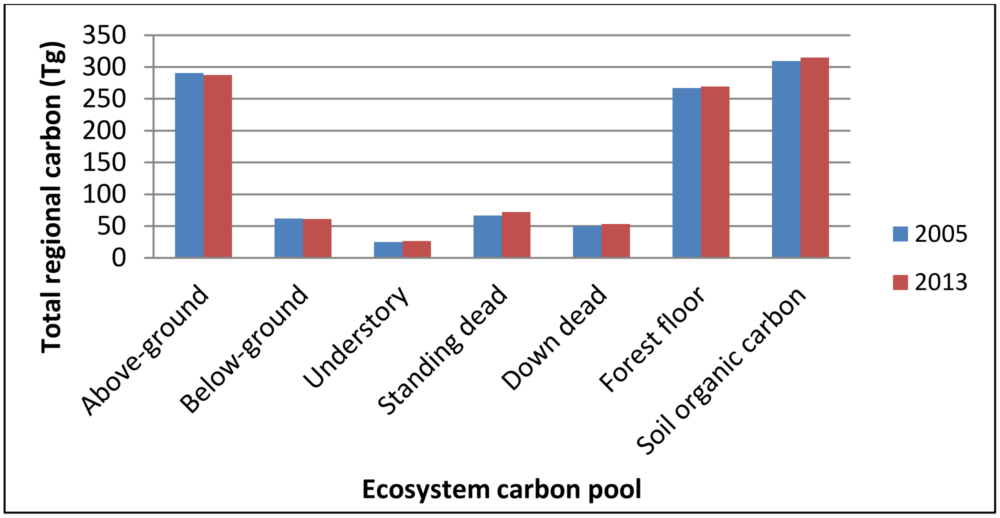

Figure 5. Carbon stocks in the seven forest ecosystem pools in national forest lands of the Intermountain Region for 2005 and 2013.

Carbon density is an estimate of forest carbon stocks per unit area. The regional graph shows a slight decrease in carbon density from 2005 to 2013, with 48.15 t/ac in 1990 and 48.06 t/ac in 2013 (Figure 6). In 2013, the Bridger-Teton NF has the highest carbon density, approximately 62.1 t/ac, while the Desert Range Experiment Station has the lowest, approximately 20.8 t/ac (Figure 7). The carbon density of the remaining national forests falls between these values. Factors such as disturbances and changes in land use, including timber harvest, and site quality may be responsible for these observed trends. The relationship of various factors to carbon density is currently being assessed and will be forthcoming.

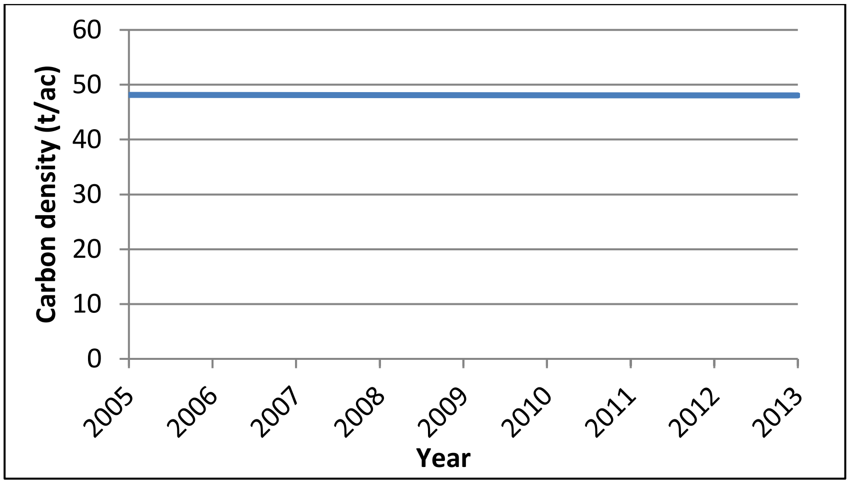

Figure 6. Carbon density (tonnes/acre) for the Intermountain Region from 2005 to 2013.

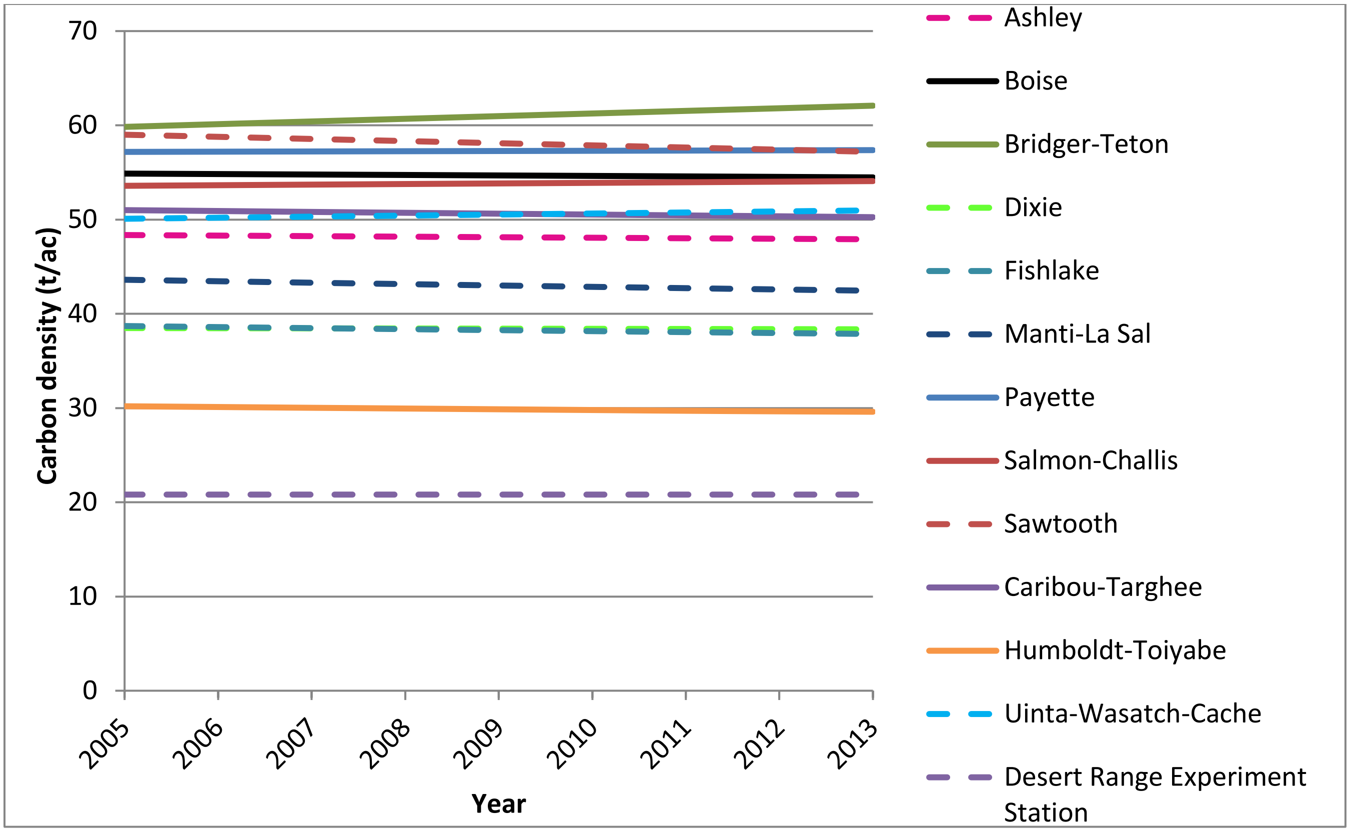

Figure 7. Carbon density (tonnes/acre) for the national forests in the Intermountain Region from 2005 to 2013.

4.2 Harvested Wood Products (HWP)

4.2.1 Methodology

This report uses the Intergovernmental Panel on Climate Change (IPCC) production accounting approach to estimate HWP carbon storage from 1911 to 2012. This approach tracks the entire cycle of carbon from harvest to timber products to primary wood products to end use to disposal. These calculations were carried out using an online HWP carbon accounting tool (http://maps.gis.usu.edu/HWP).

Regional harvests have been documented in detailed cut-and-sold reports that are available online and include the value and volume of timber sold and harvested in the region (USFS 2013). The carbon in HWP from timber products to primary products is based upon the methodology in Smith et al. (2006). And lastly, the historical end use data for the Intermountain Region is based on McKeever (2009) and McKeever and Howard (2011) which is a national data set used for all NFS regions for the distribution of primary products to end uses for all regions. For the purposes of this report, the HWP carbon pool includes both products in use and products that have been discarded to solid waste disposal sites (SWDS).

4.2.2 Limitations and Uncertainty

Modeling under this production approach accounts for wood harvested from a specific area. Some historic annual harvests have been adjusted to the modern regional boundaries, as the land base area has varied over time due to land exchanges, divestments, acquisitions, and consolidations making the geographic boundary inconsistent. Conversion factors, and the ratios used to distribute timber products to primary products, and distribute primary products to end uses have also changed over time. Since few old records for these ratios exist recent averages were applied retrospectively. The carbon in HWP from timber products to primary products is based upon historic data from several regions of the US, which tracked how wood flowed from harvested timber products to primary products to end-uses, as provided in Smith et al. (2006). For years 1950 through 2012, annual primary wood product output was distributed to specific end uses according to annual wood product consumption estimates in McKeever (2009, 2011). Fuelwood products are assumed to have full emissions with energy capture in the year they were produced. Carbon from burned and composted discarded products is assumed to be emitted without energy capture. The approach does not account for the difference between methane and CO2 emissions from landfills in terms of CO_2 equivalents. Furthermore, the approach used by Stockmann et al. (2012) does not account for all emissions associated with HWP, such as harvest or transportation emissions, which are thought to represent a relatively small fraction of the carbon stored in HWP pools (Healey et al. 2009, Loeffler et al. 2009). Neither does Stockmann's approach incorporate carbon fluxes associated with product substitution such as the substitution of HWP for metal or concrete.

Stockmann et al. (2014) identified the most critical sources of uncertainty in the analysis (i.e. reported harvest, timber product ratios, primary product ratios, etc.), developed 23 probability distributions for these sources of uncertainty (following the approach used by Skog 2008) and carried out simulations to determine the collective effect of uncertainty in these variables on estimates of HWP stocks in their recent paper. Estimates describing uncertainty associated with point estimates for HWP carbon storage and emission were calculated using a Monte Carlo simulation approach, which produces a large number of estimates drawing from expert opinion informed ranges for all variables deemed prone to error.

Refer to Stockmann et al. 2014 for detailed descriptions of additional limitations and uncertainty calculations.

4.2.3 Results

Annual timber harvests in the Intermountain Region remained below 0.065 Tg (65,000 MgC) yr^{-1} between 1911 and 1923. Harvests increased to approximately 0.103 Tg (103,000 MgC yr^{-1}) in 1925, before decreasing once again during the Great Depression period. From the mid-1950s to the 1990s, levels remained between 0.340 Tg and 0.660 Tg (340,000 and 660,000 MgC yr^{-1}). It peaked in 1972 exceeding 0.658 Tg (658,000 MgC). Harvests declined in the mid-1990s and reached a low in 2005 of approximately 0.085 Tg (85,000 MgC). Small increases have occurred since then, however levels have remained below 0.155 Tg (155,000 MgC yr^{-1}) (Figure 8).

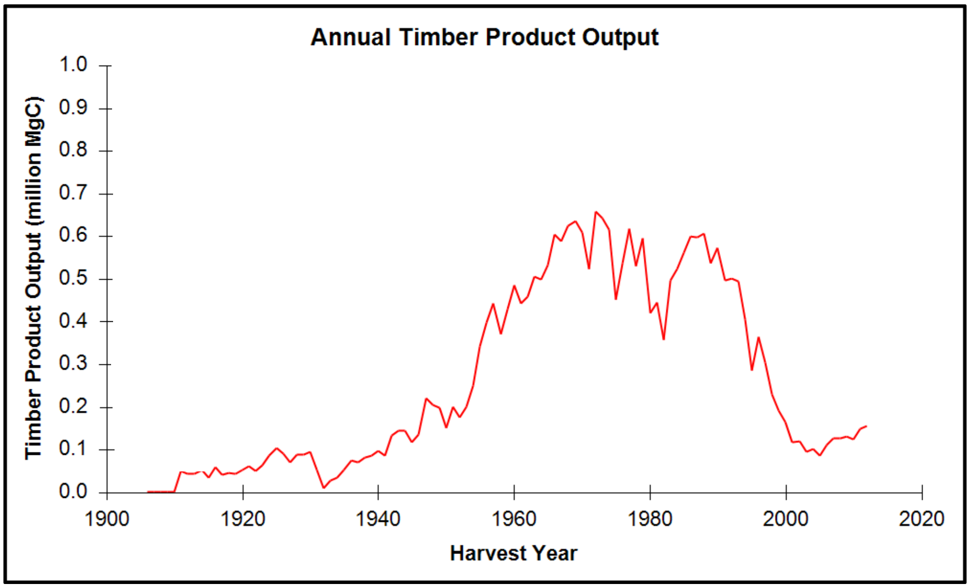

Figure 8. Annual timber product output in the Intermountain Region, 1911 to 2012. Harvest estimates are based on data collected from USDA Forest Service Archives and Cut/Sold reports (Stockmann et al. 2014).

The cumulative carbon stored in the Intermountain Region HWP accelerated around 1955 and increased until 2000, peaking at 9.5 Tg (9.5 million MgC) in storage. Since 2000, carbon stocks have been in a slow decline and by 2013, the pool has fallen to approximately 9 Tg (9 million MgC) (Figure 9). Because the amount of HWP carbon entering that pool is less than the amount of carbon exiting it through various pathways, HWP stocks are decreasing.

In the context of total forest carbon, including both ecosystem carbon and HWP carbon, we estimate that the Intermountain Region HWP carbon stocks represent roughly 0.82% of total forest carbon storage associated with national forests in the Intermountain Region in 2012.

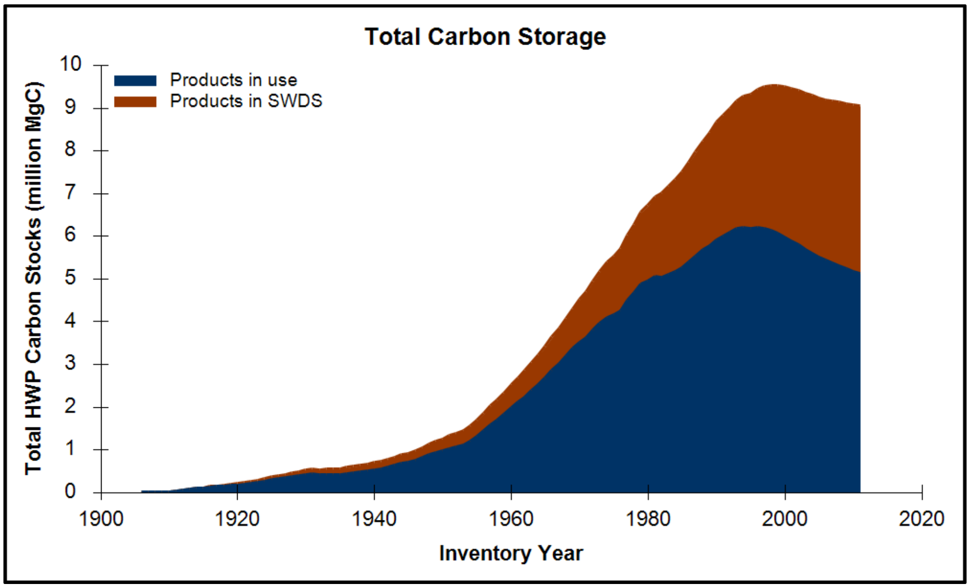

Figure 9. Cumulative total carbon stored in HWP manufactured from Intermountain Region timber using the IPCC/EPA approach. Carbon in HWP includes both products that are still in use and carbon stored at solid waste disposals sites (SWDS), including landfills and dumps (Stockmann et al. 2014).

For an in-depth analysis of the Intermountain Region HWP modeling, see Stockmann et al. (2014).

Carbon stocks are affected by disturbances such as wildfires, insect activity, timber harvesting, and weather events. Companion assessments are being completed to understand these influences to grasp a more complete picture of forest carbon dynamics and the role of management (Healey et al. 2014).

Total forest carbon (forest ecosystem and HWP carbon) stock change is estimated at 1.91 Tg carbon/year for Region 4 for the baseline period 2005 to 2013. This value represents the net sequestration rate of carbon by forests in Region 4.

5.0 Contacts

Contact Christopher Woodall (christopher.w.woodall@usda.gov) for assistance with ecosystem data, Keith Stockmann (keith.stockmann@usda.gov) for assistance with HWP data, and Lauren Onofrio (lauren.onofrio@usda.gov) for other questions.

6.0 Glossary

Carbon density. An estimate of forest carbon stocks per unit area (e.g., tonnes [Mg] per acre of carbon in standing live trees).

Carbon pool. Any natural region or zone, or any artificial holding area, containing an accumulation of carbon or carbon-bearing compounds or having the potential to accumulate such substances.

Carbon sink. Natural or man-made system that absorbs more carbon than it releases.

Carbon stocks. The amount or quantity contained in the inventory of a carbon pool.

Carbon stock change. The change in carbon stocks over time, calculated by taking the difference between successive inventories and dividing by the number of years between these inventories for each national forest. A positive change means carbon is being removed from the atmosphere and sequestered by the forests (i.e., carbon sink) while a negative change means carbon is added to the atmosphere by forest-related emissions (i.e., carbon source).

Flux. The transfer of carbon from one carbon pool to another.

Forest land. A land-use category that includes areas at least 36.6 m (120 feet) wide and 0.4 ha (1 acre) in size with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between forest and non-forest lands that have at least 10 percent cover (or equivalent stocking) with live trees and forest areas adjacent to urban and built-up lands. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 36.6 m and continuous length of at least 110.6 m to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if they are less than 36.6 m wide or 0.4 ha in size; otherwise they are excluded from Forest Land and classified as Settlements. Tree-covered areas in agricultural production settings, such as fruit orchards, or tree-covered areas in urban settings, such as city parks, are not considered forest land (Smith et al. 2009).

Greenhouse gas. Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere.

Harvested wood products (HWP). HWP includes all wood material (including bark) that leaves harvest sites. Slash and other material left at harvest sites should be regarded as dead organic matter.

Mitigation (Climate Change). An intervention to reduce the emissions or enhance the storage of greenhouse gases. Mitigation strategies include, but are not limited to, the following:

1. Promoting the uptake of atmospheric carbon by forests and the storage of carbon in soils, vegetation, long-lived wood products, and recycled wood materials.
2. Indirectly reducing greenhouse gas emissions (for example, through the use of carbon-neutral bioenergy to offset fossil fuel emissions and substituting wood for more fossil fuel-intensive building products).
3. Diminishing greenhouse gas emissions (for example, through the cooling effects of urban forests, which reduce the need for fossil fuels to run air conditioners) or through more prudent consumption in facilities, fleet, and other operations.

Monte Carlo simulation. The principle of Monte Carlo analysis is to perform the inventory calculation many times by computer, each time with the uncertain factors or parameters and activity data chosen randomly within the distribution on uncertainties specified by the user.

Sequestration. The direct removal of CO_2 from the atmosphere through biologic processes such as forest growth.

Woody biomass. The by-product of management, restoration, and hazardous fuel reduction treatments, as well as the product of natural disasters, including trees and woody plants (limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment).

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Woodall, C., Smith, J. & Nichols, M. 2013. Data sources and estimation/modeling procedures for National Forest System carbon stocks and stock change estimates derived from the US National Greenhouse Gas Inventory. https://www.fs.usda.gov/sites/default/files/nfs-carbon-methodology.pdf

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9.0 Appendix A: NFS Carbon Stocks and Stock Change with Uncertainties

The graphs below display total forest ecosystem carbon stocks and carbon stock change data for each NFS unit for Region 4 for the baseline period 2005 to 2013 bounded by uncertainty values represented by the green bands.

Carbon stocks are based on plot-level data samples. Live and standing dead trees are directly measured on each plot with application of volume/biomass/carbon (i.e., allometric) models to estimate their carbon. For other pools, such as the forest floor samples, a variety of carbon models are employed to estimate their stocks based on general site and stand attributes. These estimates are then expanded using remotely sense imagery to represent carbon stocks on the entire area of interest, in this case, each national forest.

Carbon stock change is the change in carbon stocks over time, calculated by taking the difference between successive inventories and dividing by the number of years between these inventories for each national forest (Woodall et al. 2013). Stock change for a given year is the change between that year and the following year, so that the stock change for 2013 is the change between 2012 and 2013. A negative change in the graphs below means carbon is being removed from the atmosphere and sequestered by the forests (i.e., carbon sink) while a positive change means carbon is added to the atmosphere by forest-related emissions (i.e., carbon source).

Uncertainty estimates are produced using a statistical technique called the Monte Carlo method. In this method, many simulations are performed using input data and statistical models. Model simulations were repeated 2000 times on each national forest; by this point, the estimates of uncertainty were stabilized. Input data for each simulation were randomly generated within the possible range of all values for each plot for each carbon pool. The possible range of values varied from pool to pool and was dependent on many factors; for example, in the live tree pool, important factors included tree species, number of trees, and area of each plot among many others.

The estimation procedure takes into account problems with the underlying data, such as unsampled areas in older inventories and inconsistencies in the various models. However, due to these sources of error, uncertainties may be quite large. In many cases, stock change uncertainty may overlap zero for a particular national forest. In those situations we lack the statistical confidence to state that a national forest's stock change was a source or sink of carbon.

The 95% confidence intervals of the Monte Carlo results were calculated for each baseline for each national forest. This means that, 19 times out of 20, the carbon stock for any given year should fall within the highlighted (green) zone, given what we know about potential error.

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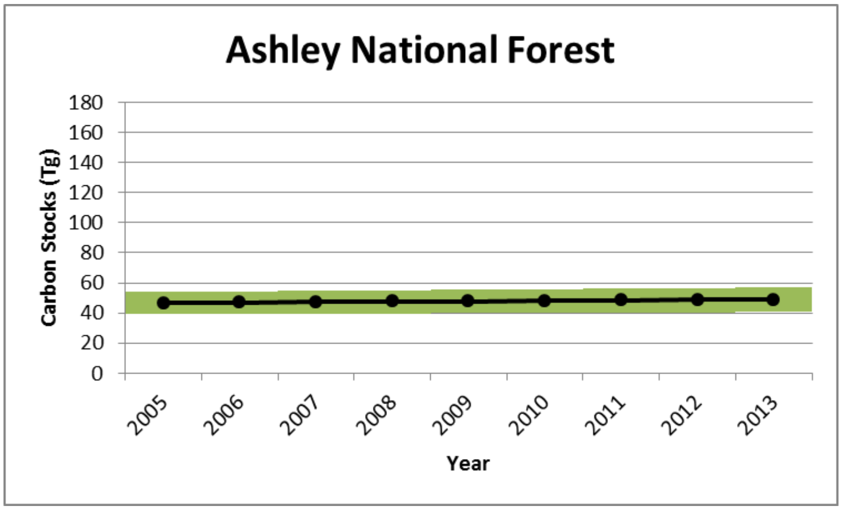
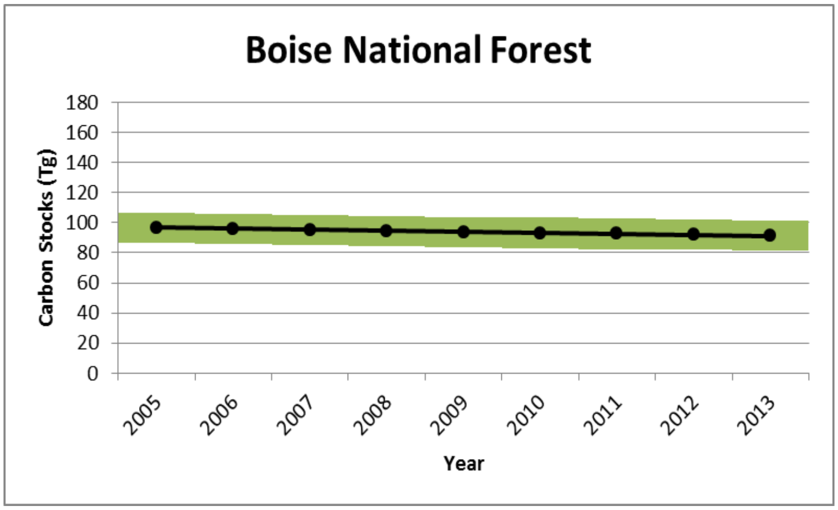
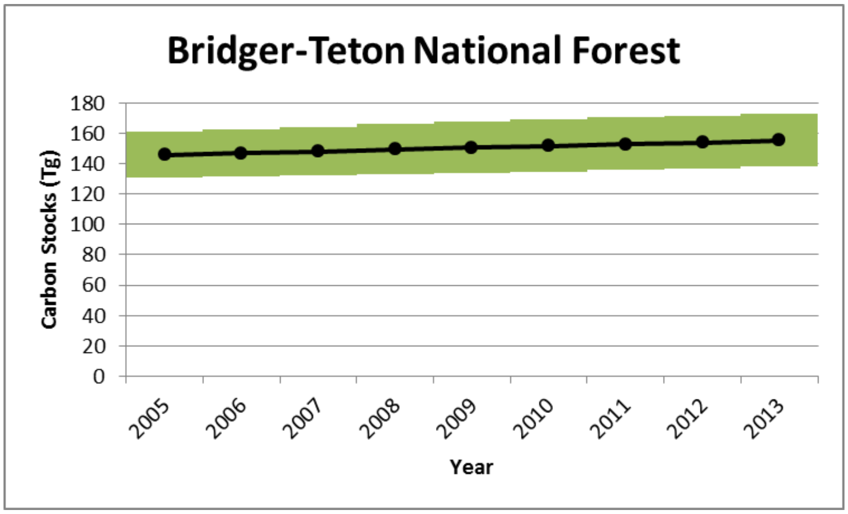
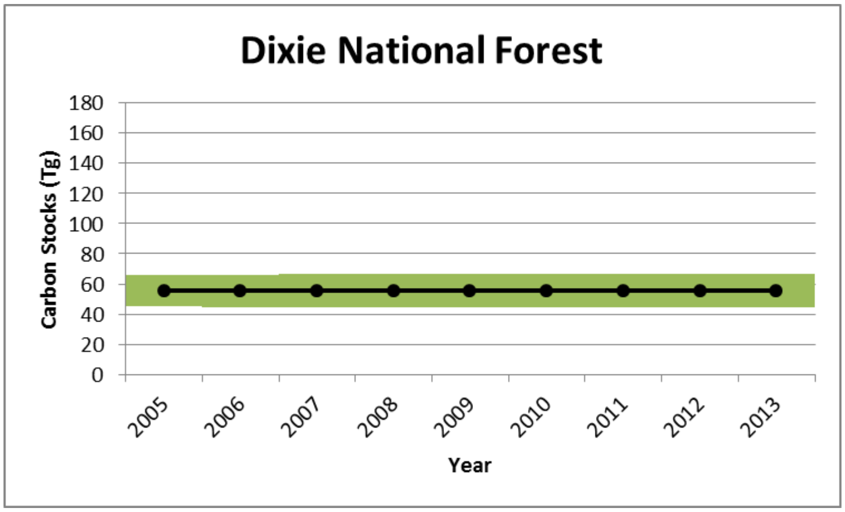
I. Total Forest Ecosystem Carbon Stocks and Uncertainty Estimates (95% confidence level)








Dixie National Forest
Carbon Stocks (Tg)
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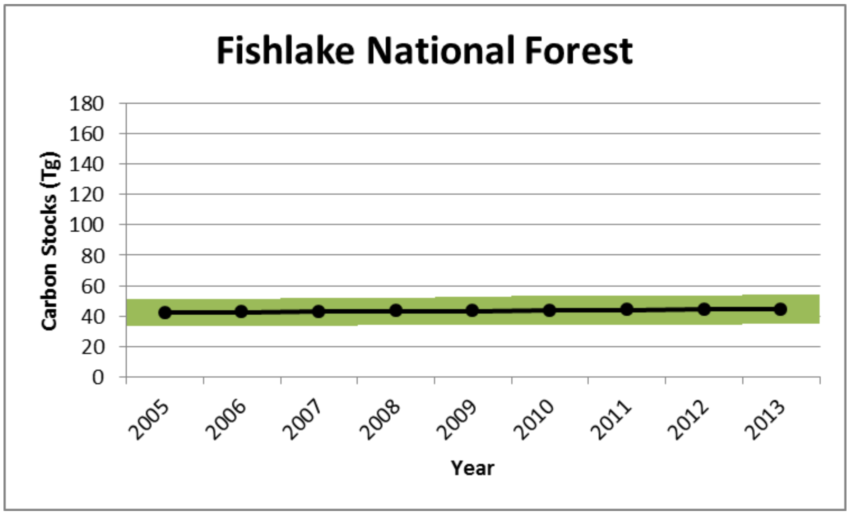
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Carbon Stocks (Tg)
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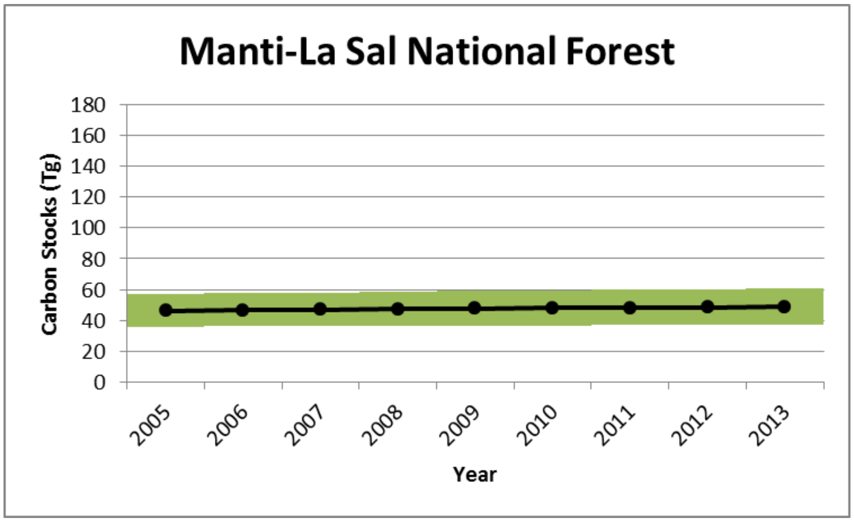
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Carbon Stocks (Tg)
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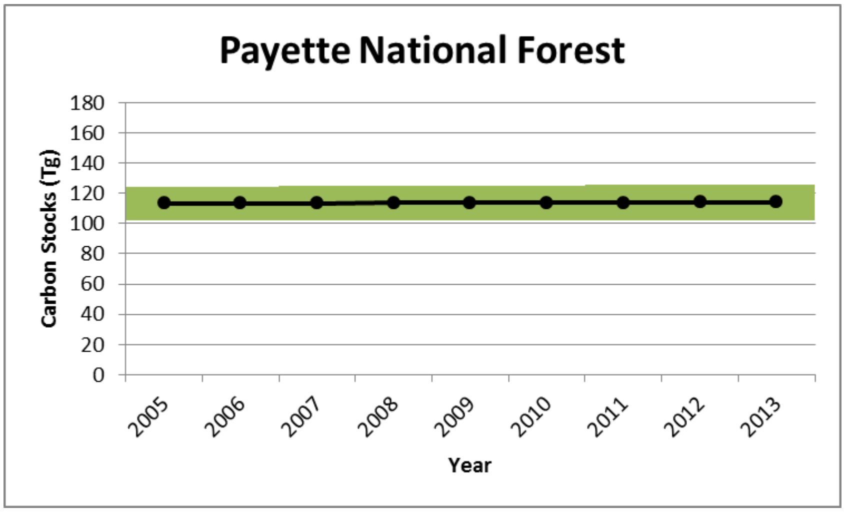
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Carbon Stocks (Tg)
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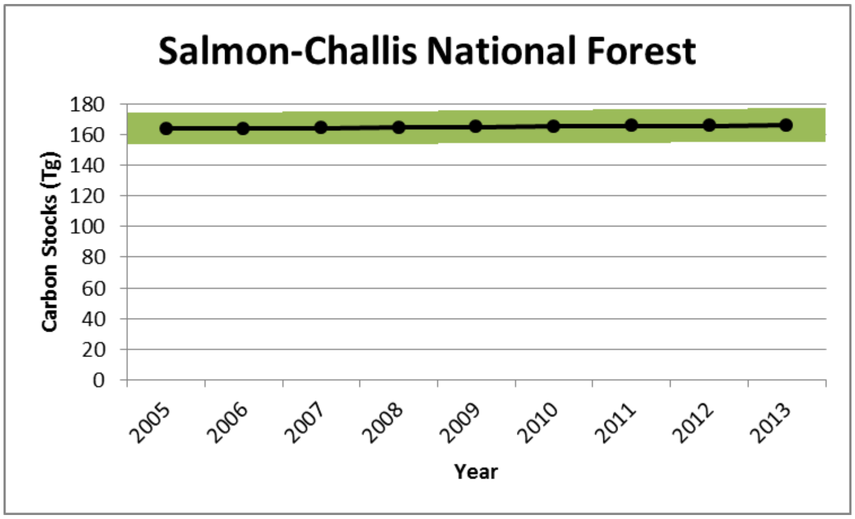
Salmon-Challis National Forest
Carbon Stocks (Tg)
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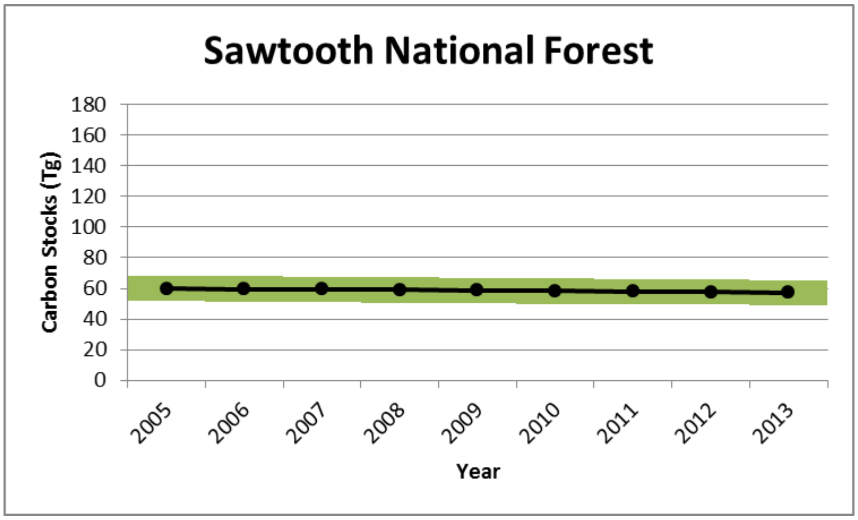
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Carbon Stocks (Tg)
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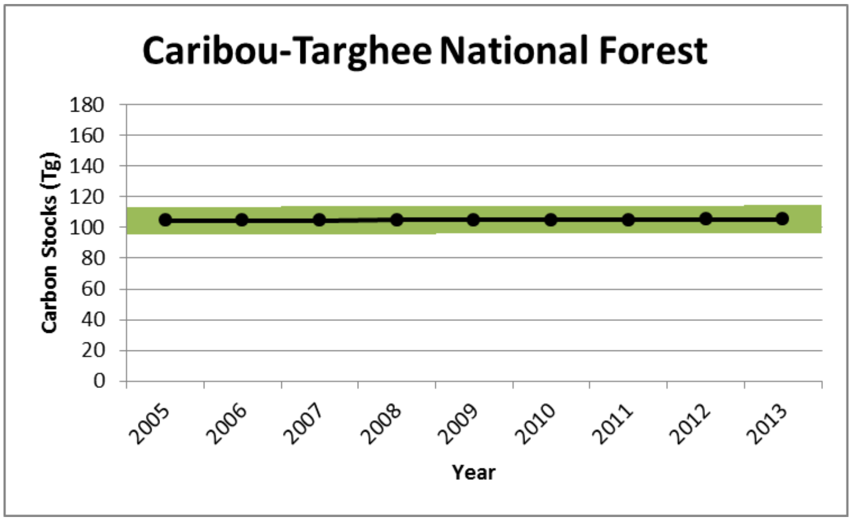
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Carbon Stocks (Tg)
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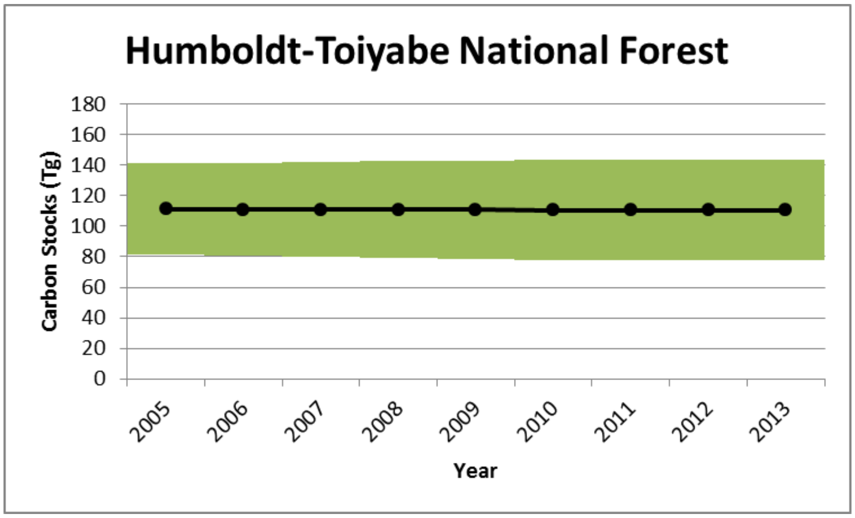
Humboldt-Toiyabe National Forest
Carbon Stocks (Tg)
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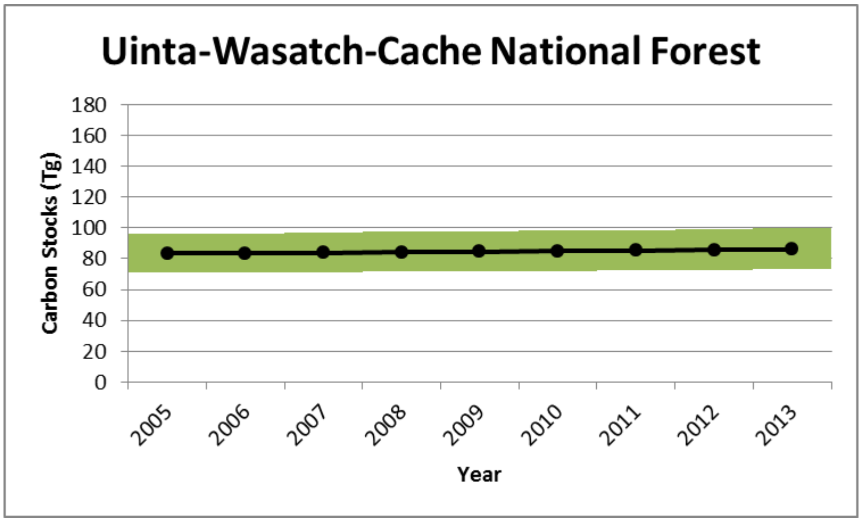
Uinta-Wasatch-Cache National Forest
Carbon Stocks (Tg)
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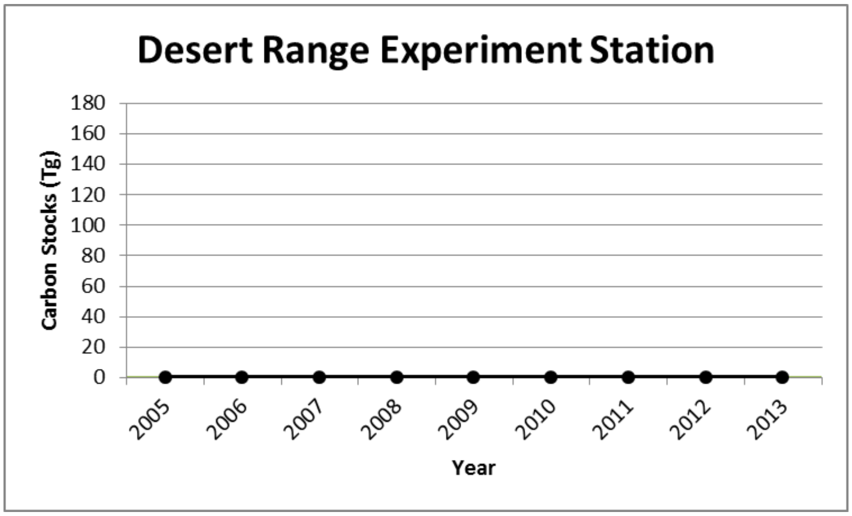
Desert Range Experiment Station
Carbon Stocks (Tg)
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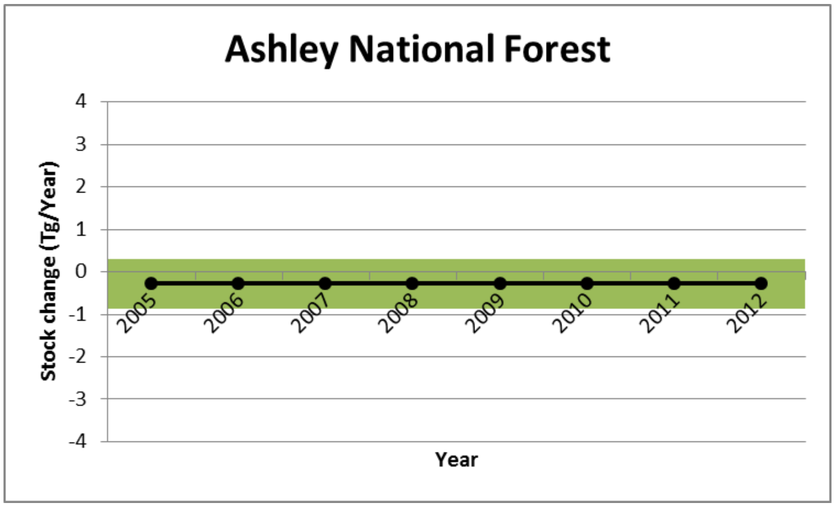
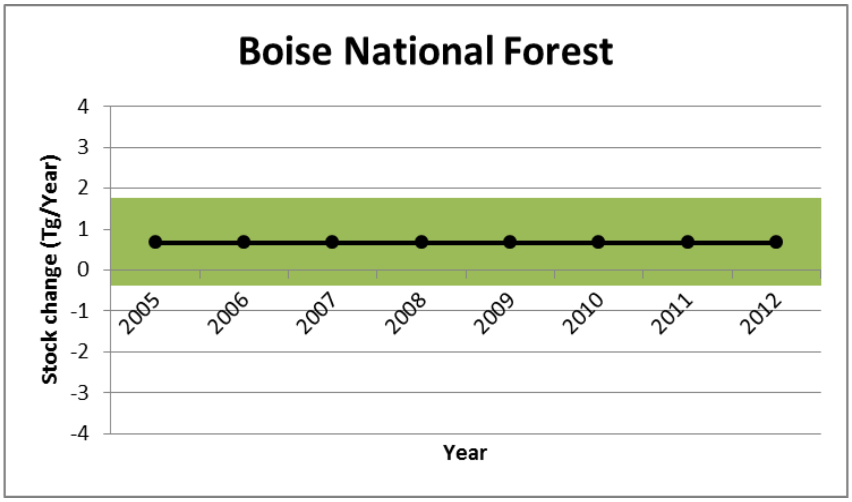
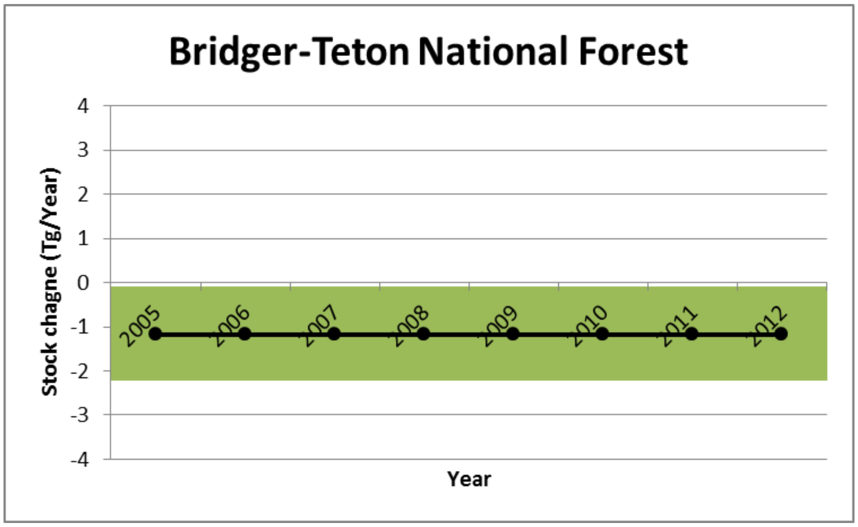
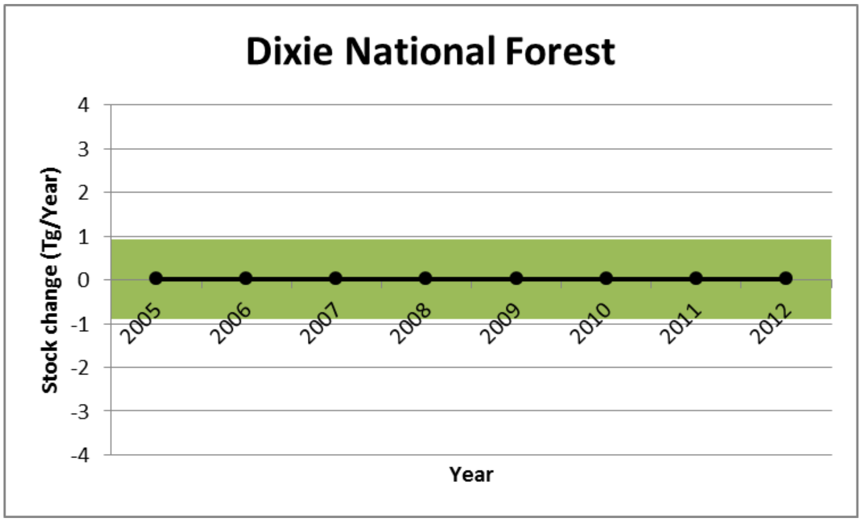
II. Carbon Stock Change and Uncertainty Estimates (95% confidence level)








Dixie National Forest
Stock change (Tg/Year)
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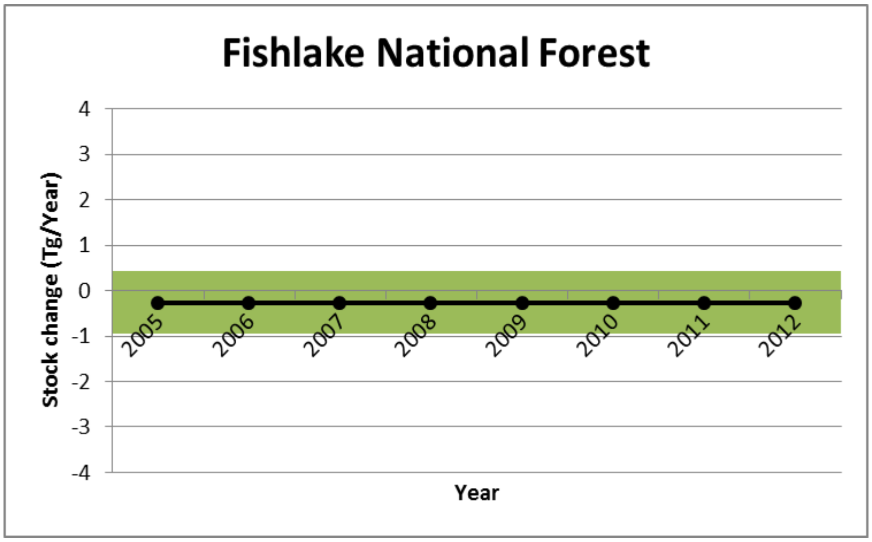
Fishlake National Forest
Stock change (Tg/Year)
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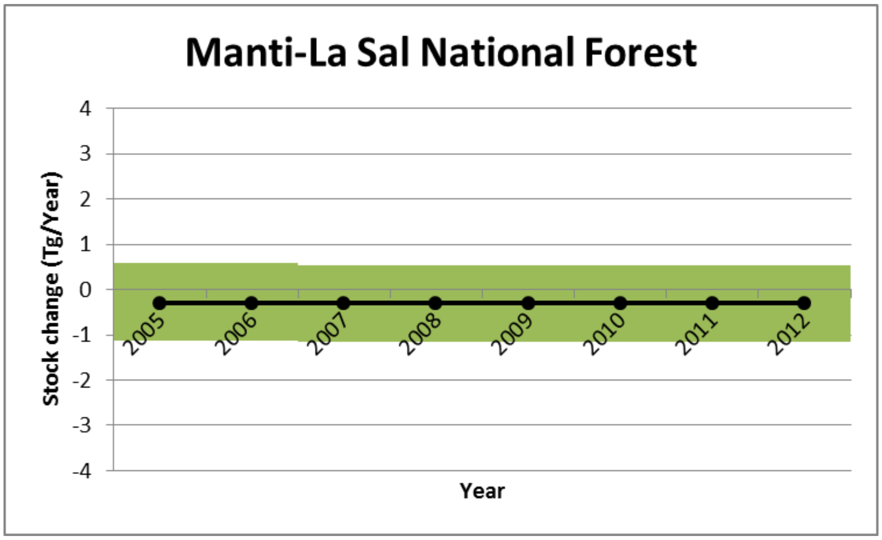
Manti-La Sal National Forest
Stock change (Tg/Year)
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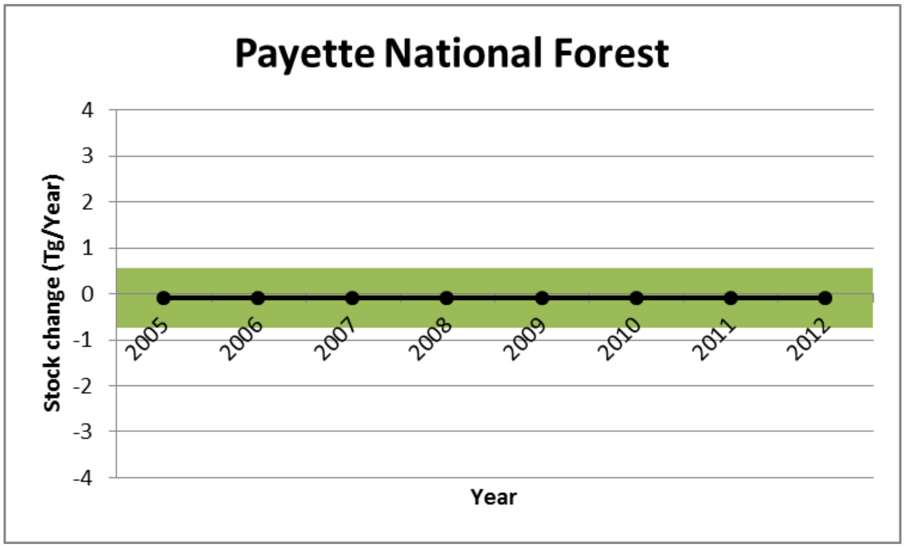
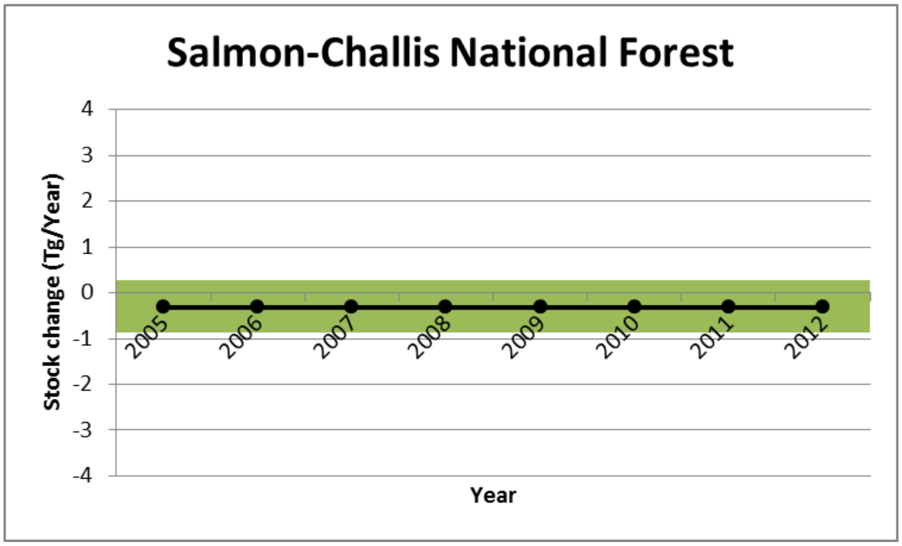
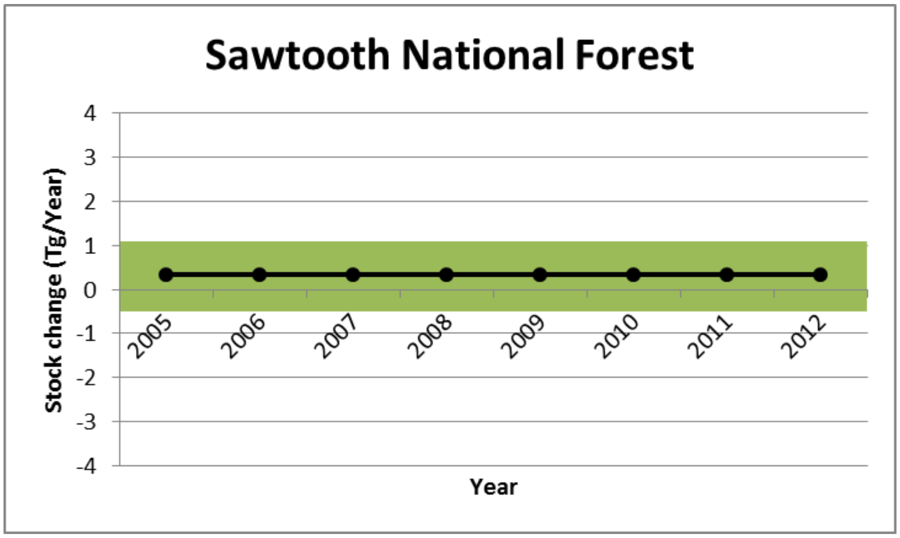
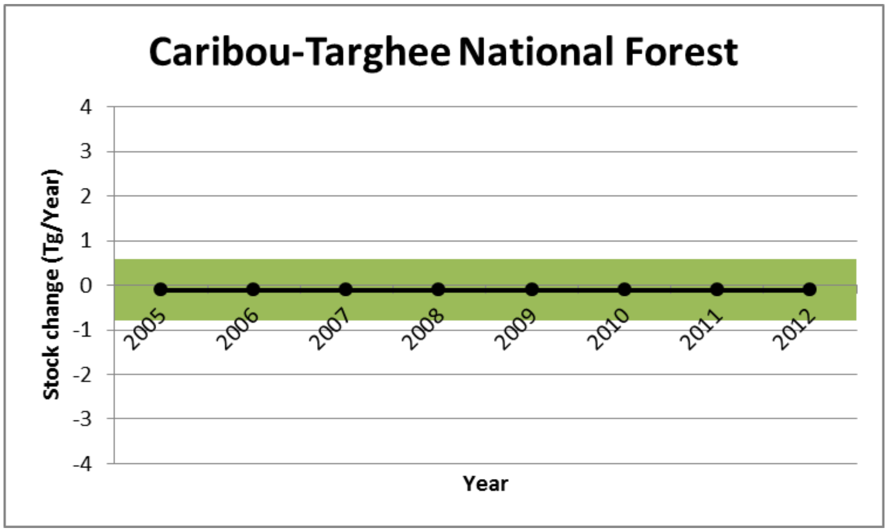
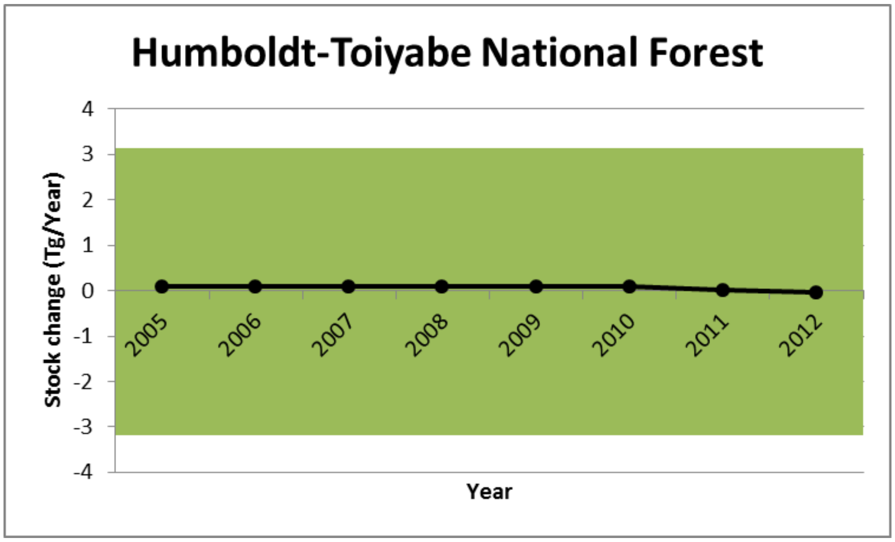
2012
Year

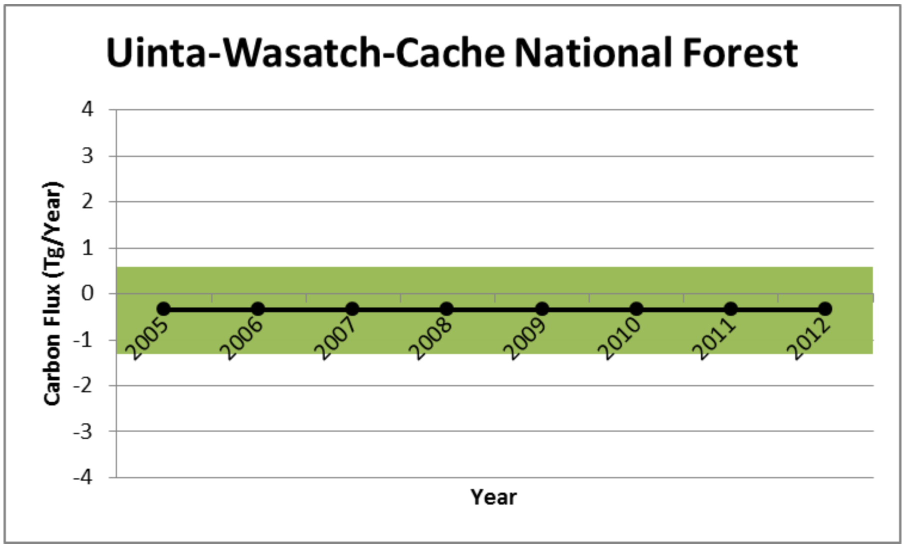

Payette National Forest
Stock change (Tg/Year)
4
3
2
1
0
-1
-2
-3
-4
2005
2006
2007
2008
2009
2010
2011
2012
Year


Salmon-Challis National Forest
Stock change (Tg/Year)
4
3
2
1
0
-1
-2
-3
-4
2005
2006
2007
2008
2009
2010
2011
2012
Year


Sawtooth National Forest
Stock change (Tg/Year)
4
3
2
1
0
-1
-2
-3
-4
2005
2006
2007
2008
2009
2010
2011
2012
Year

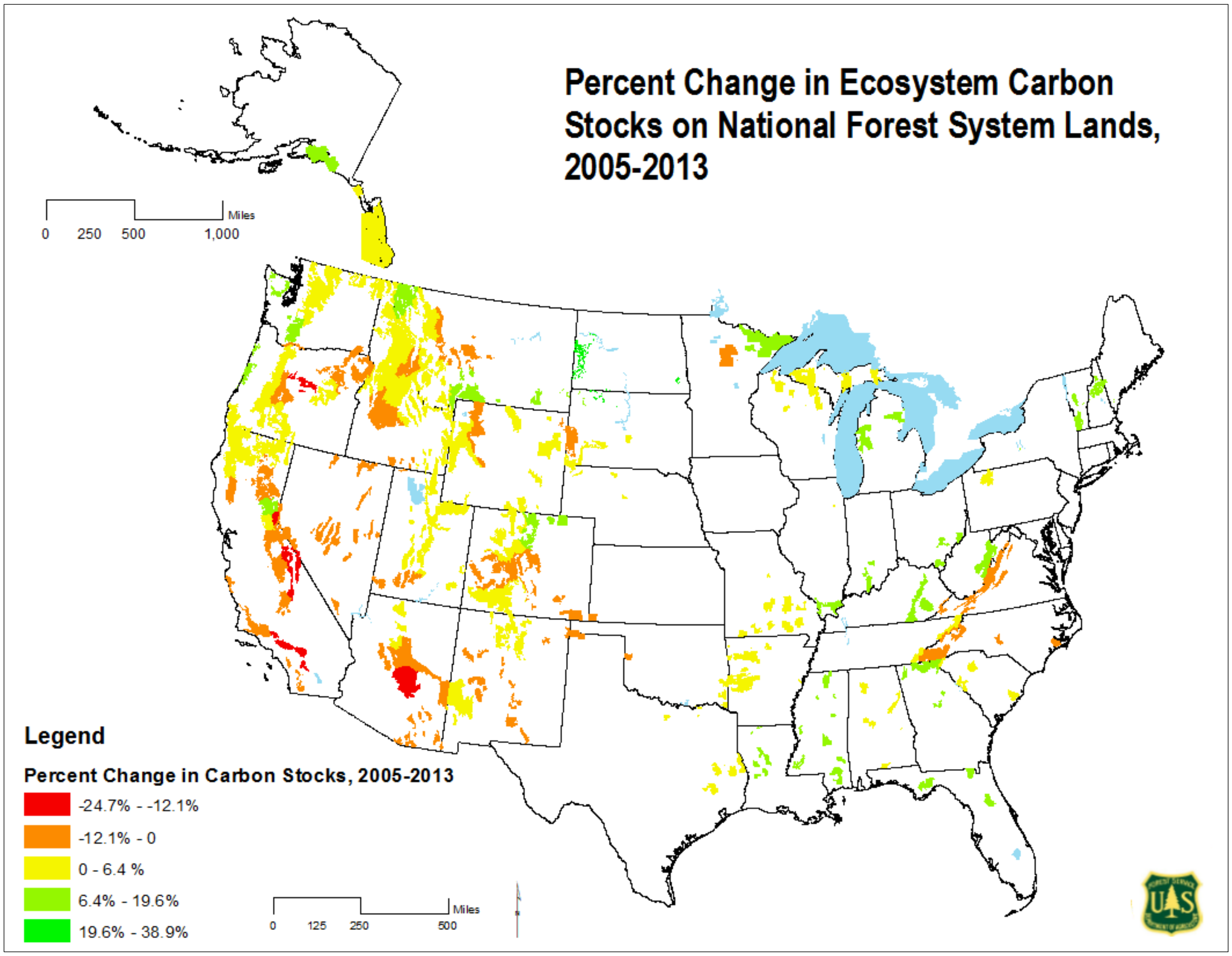

Caribou-Targhee National Forest
Stock change (Tg/Year)
4
3
2
1
0
-1
-2
-3
-4
2005
2006
2007
2008
2009
2010
2011
2012
Year

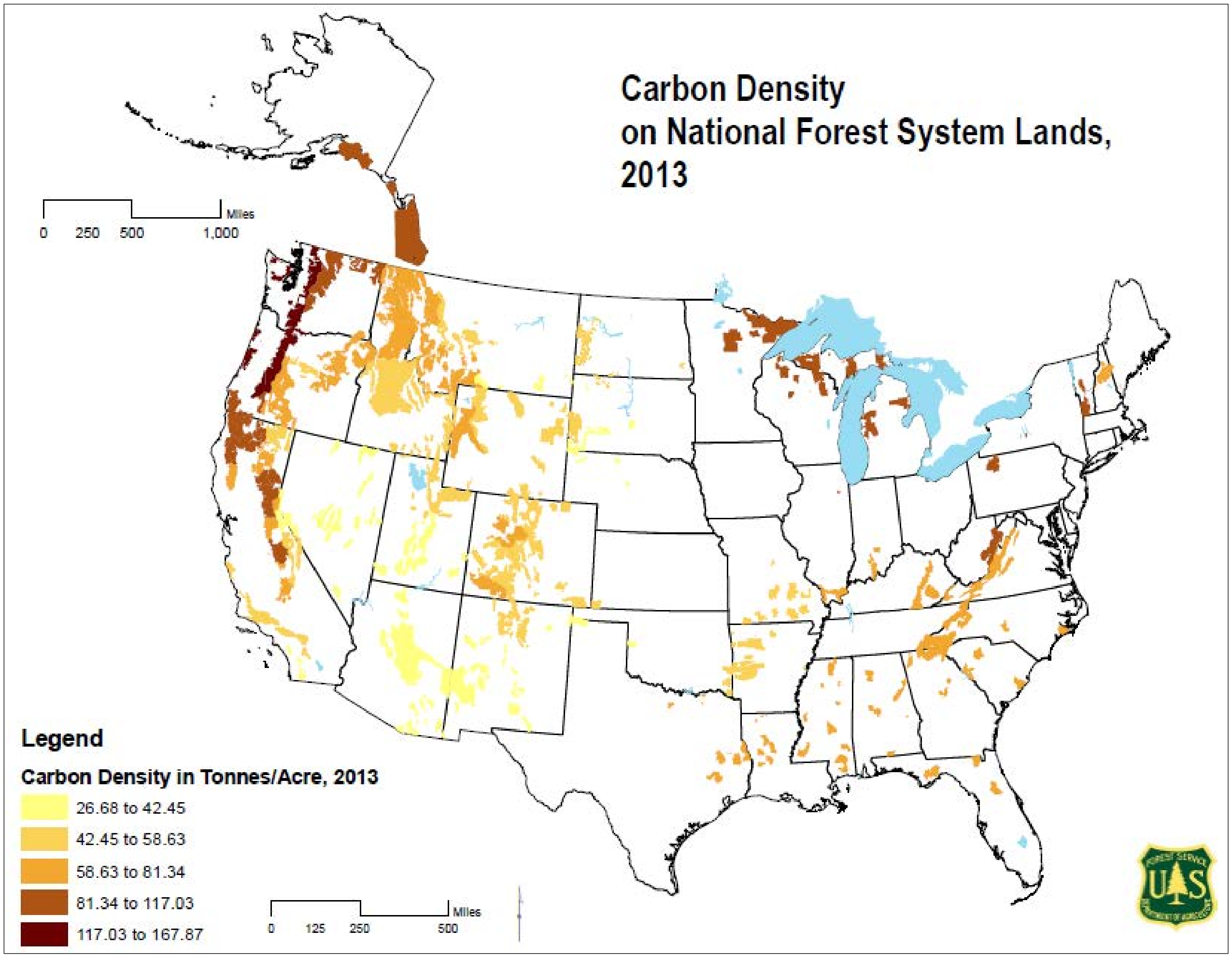

Humboldt-Toiyabe National Forest
Stock change (Tg/Year)
4
3
2
1
0
-1
-2
-3
-4
2005
2006
2007
2008
2009
2010
2011
2012
Year


Uinta-Wasatch-Cache National Forest
Carbon Flux (Tg/Year)
4
3
2
1
0
-1
-2
-3
-4
2005
2006
2007
2008
2009
2010
2011
2012
Year

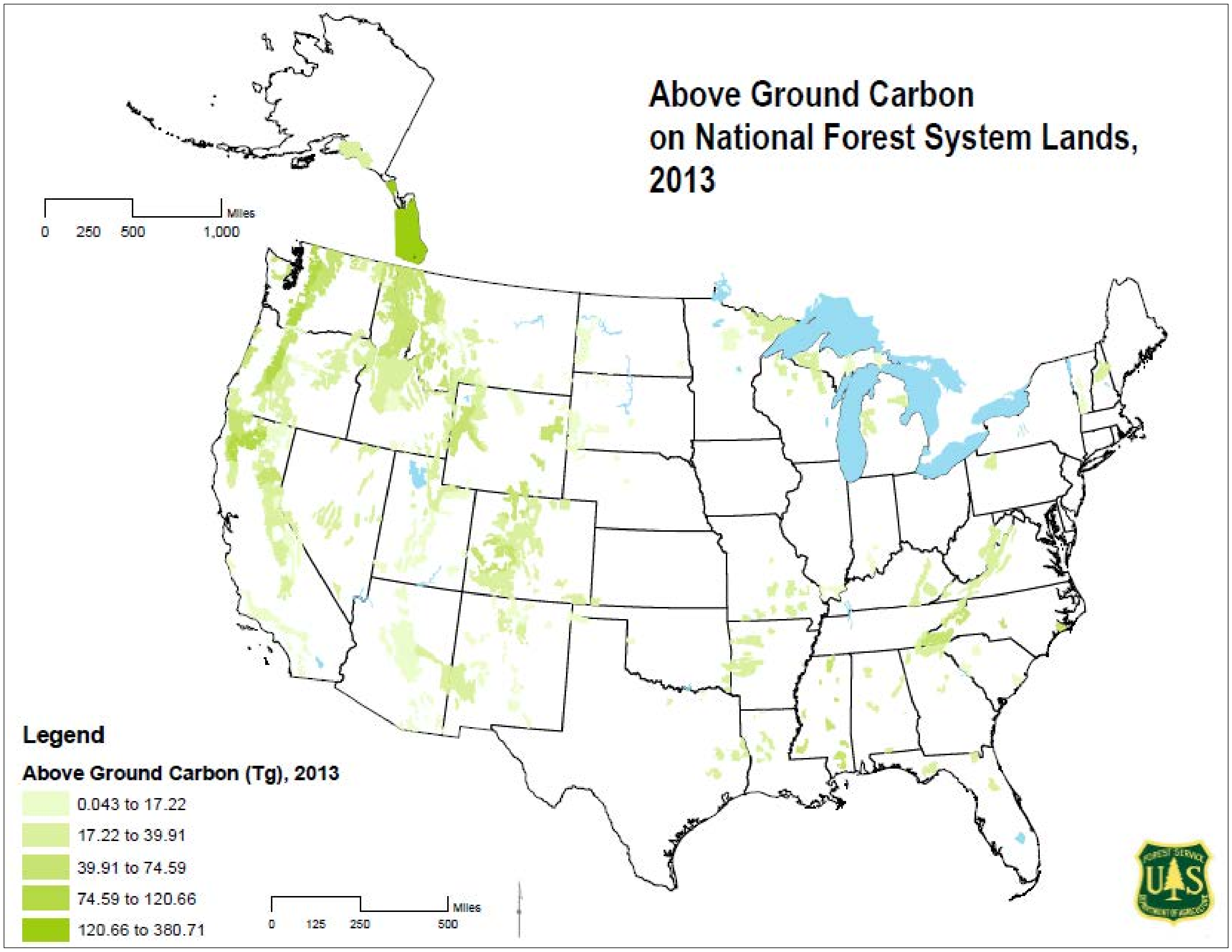
10.0 Appendix B: Maps

These maps give a national perspective and were developed using FIA estimates. These are not intended to be precisely interpretable at the forest level. The forest level results and uncertainties are communicated in the total carbon graphs in these reports. A description of the methodology used to derive uncertainty values can be found in Section 4 and Appendix A.

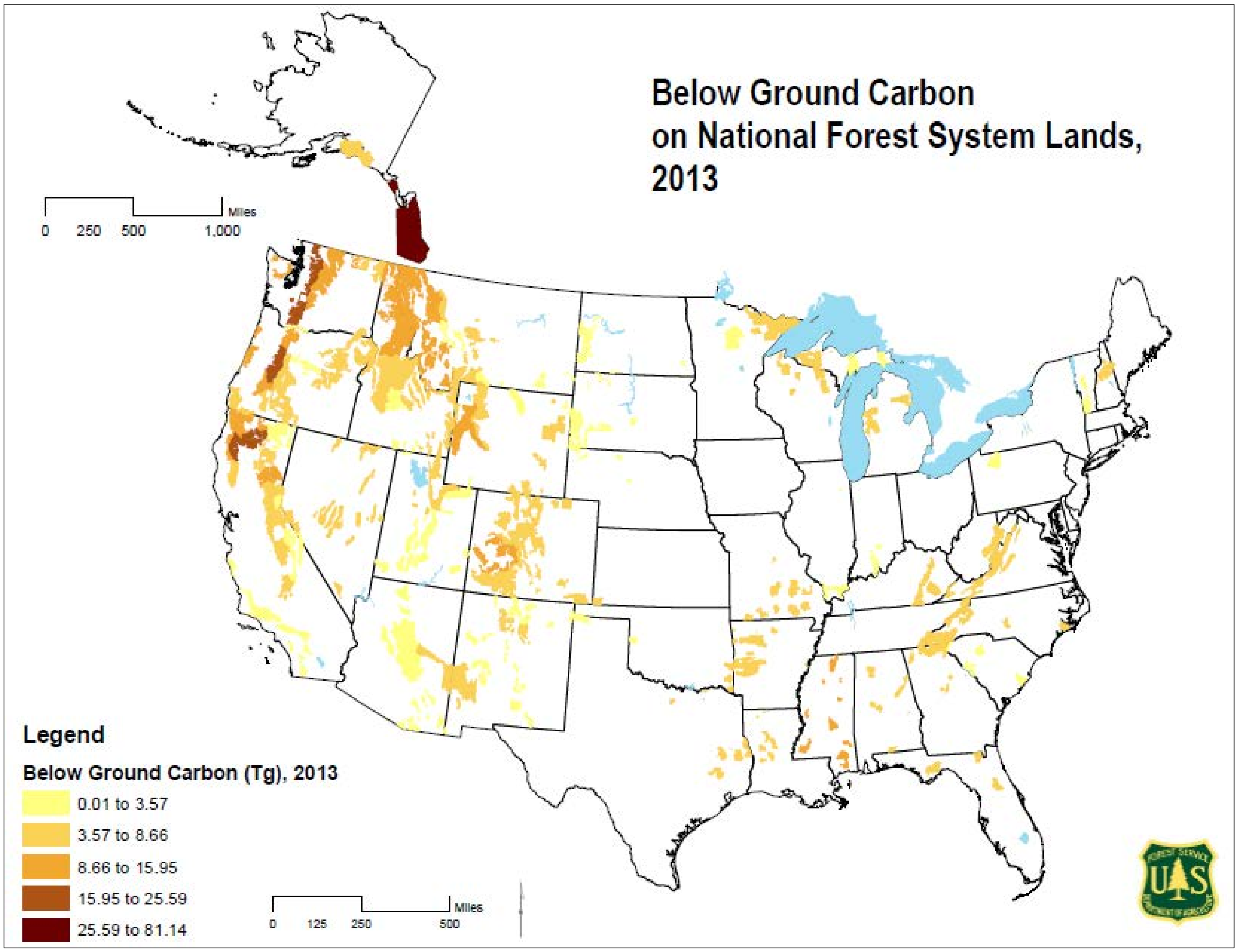




Carbon Density on National Forest System Lands, 2013



Above Ground Carbon on National Forest System Lands, 2013


Below Ground Carbon
on National Forest System Lands,
2013
Miles
0 250 500 1,000
Legend
Below Ground Carbon (Tg), 2013
0.01 to 3.57
3.57 to 8.66
8.66 to 15.95
15.95 to 25.59
25.59 to 81.14
Miles
0 125 250 500
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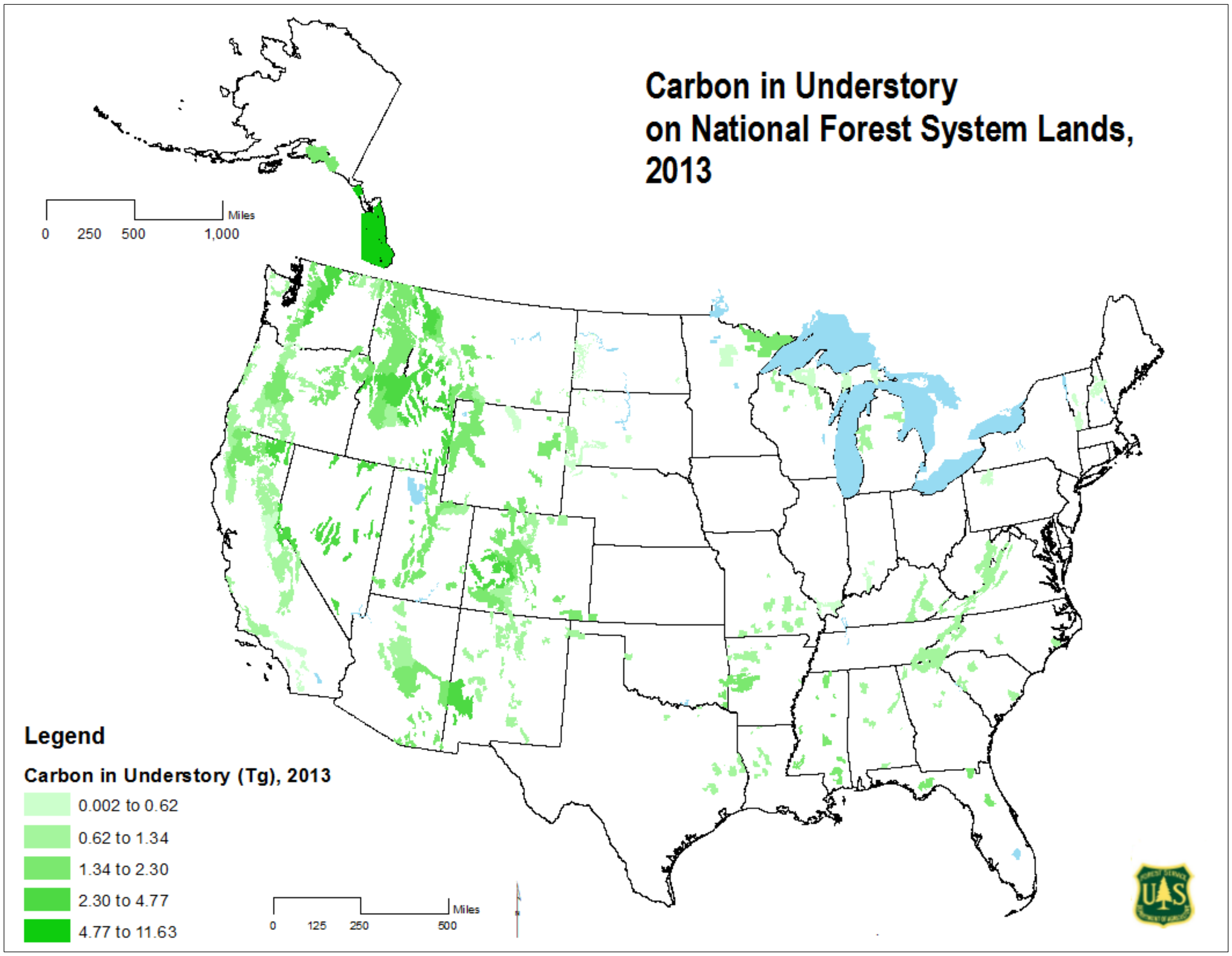
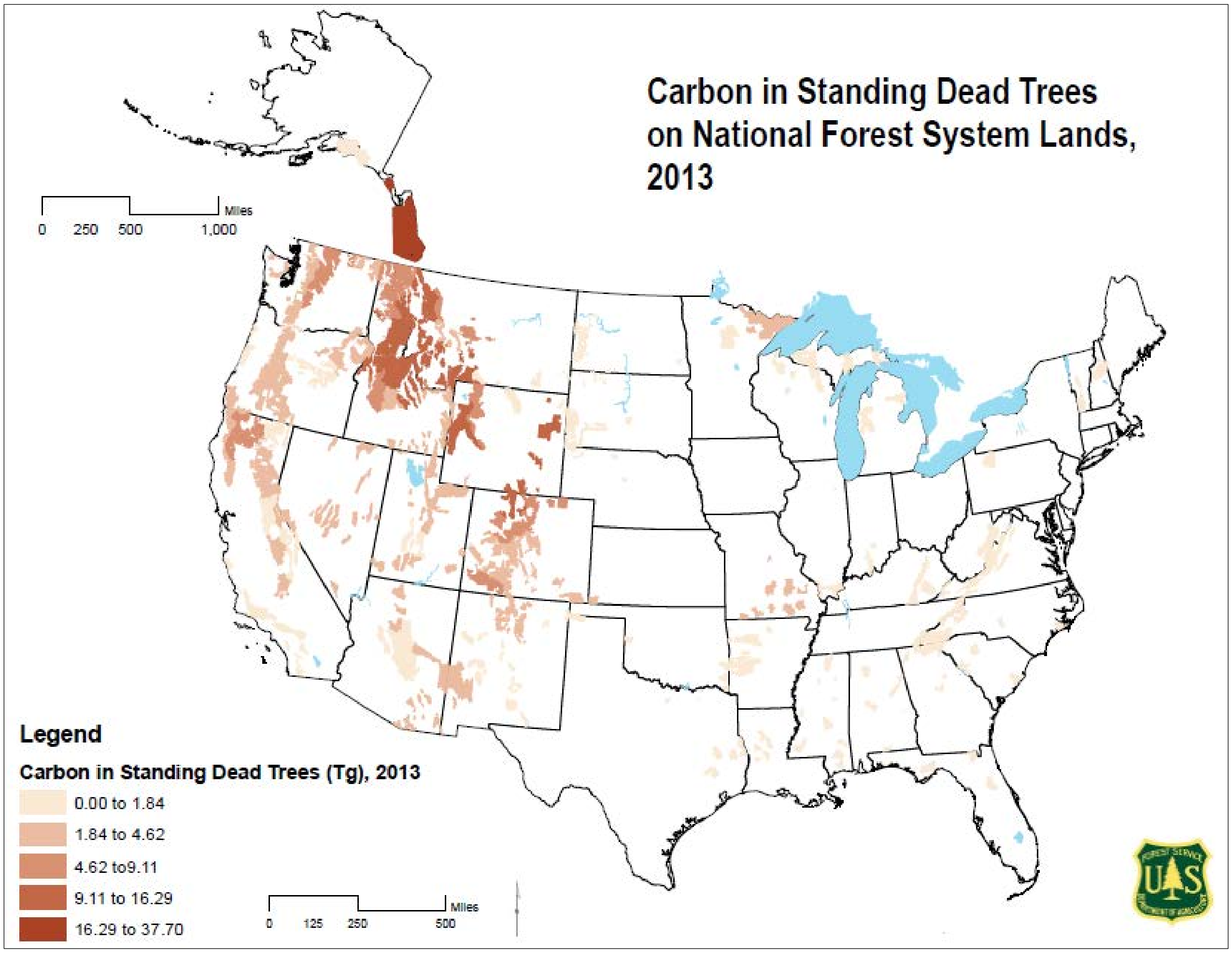
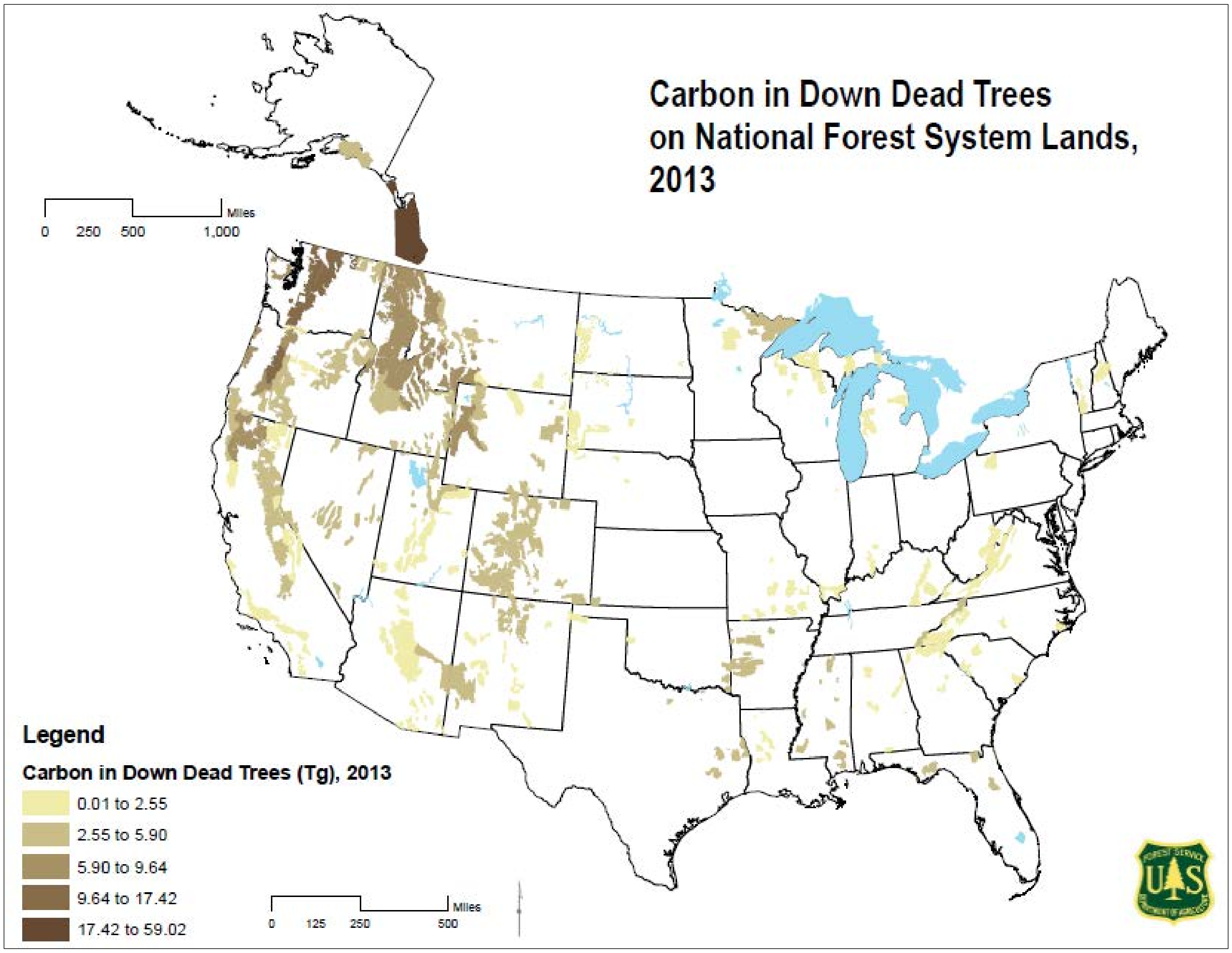
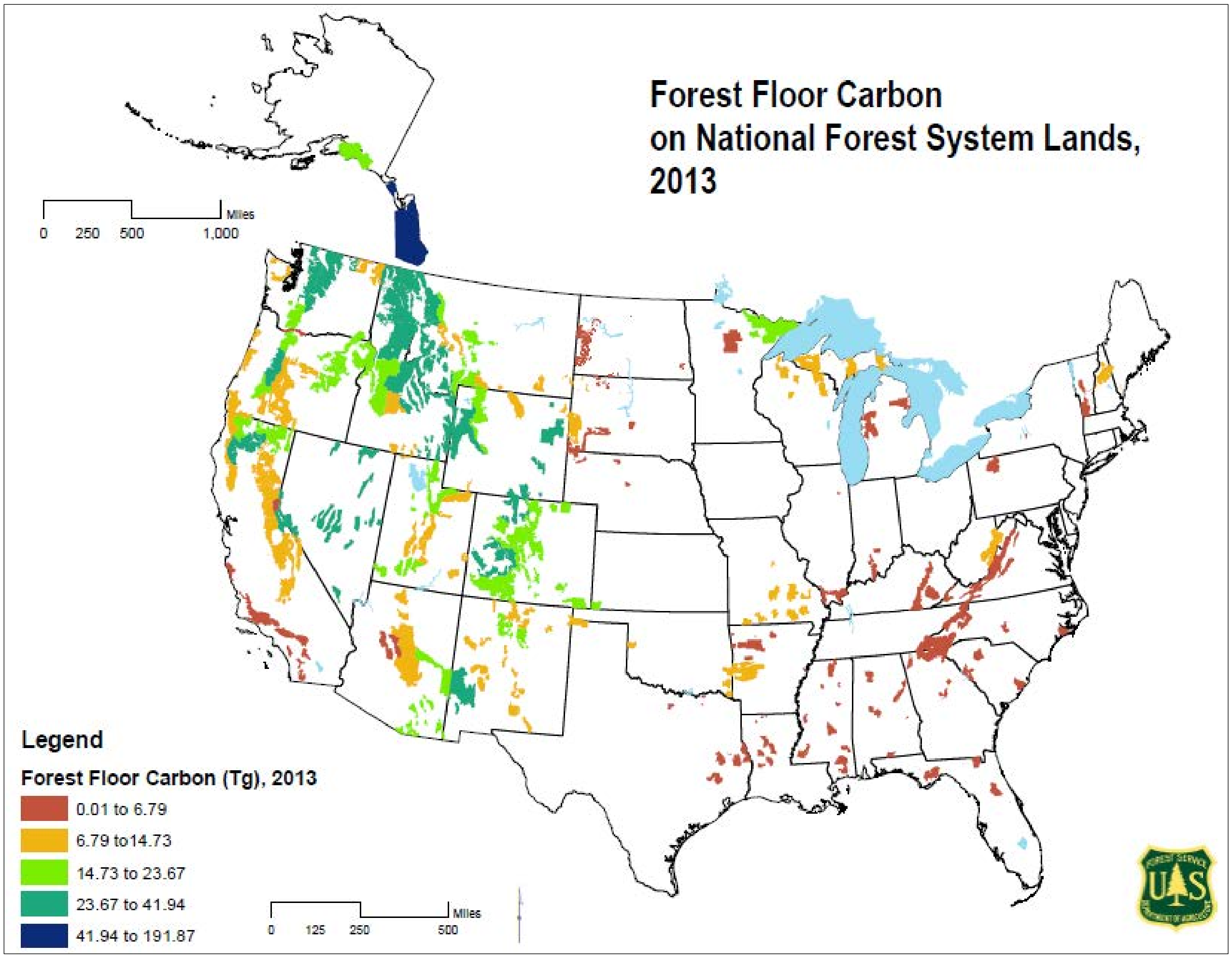

Carbon in Understory
on National Forest System Lands,
2013
0 250 500 1,000 Miles
Legend
Carbon in Understory (Tg), 2013
0.002 to 0.62
0.62 to 1.34
1.34 to 2.30
2.30 to 4.77
4.77 to 11.63
0 125 250 500 Miles

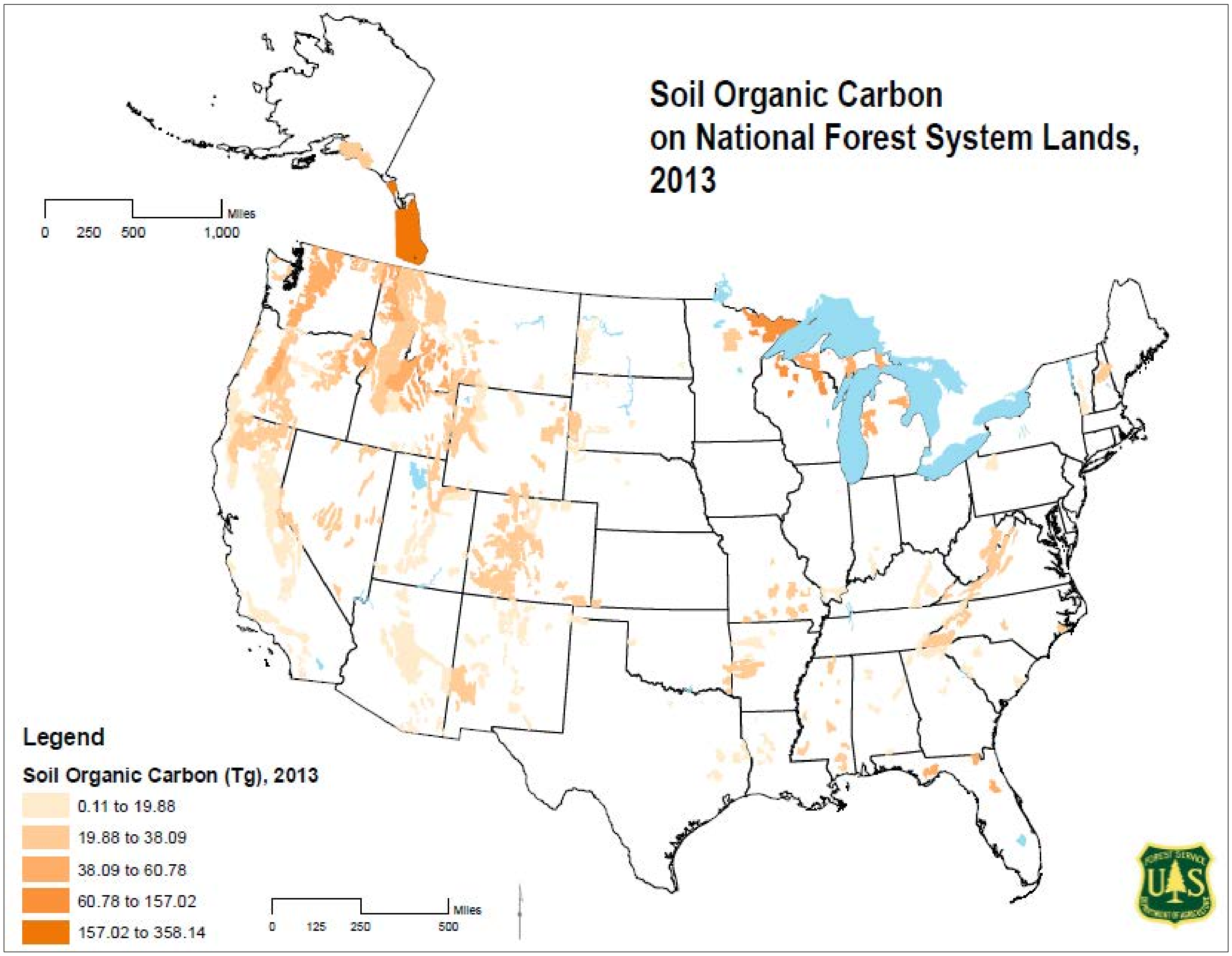

Carbon in Standing Dead Trees on National Forest System Lands, 2013
0
250
500
1,000
Miles
Legend
Carbon in Standing Dead Trees (Tg), 2013
0.00 to 1.84
1.84 to 4.62
4.62 to9.11
9.11 to 16.29
16.29 to 37.70
0
125
250
500
Miles



Carbon in Down Dead Trees on National Forest System Lands, 2013



Forest Floor Carbon on National Forest System Lands, 2013


Soil Organic Carbon
on National Forest System Lands,
2013
0
250
500
1,000
Miles
Legend
Soil Organic Carbon (Tg), 2013
0.11 to 19.88
19.88 to 38.09
38.09 to 60.78
60.78 to 157.02
157.02 to 358.14
0
125
250
500
Miles
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