

Assessment of the Influence of Disturbance, Management Activities, and Environmental Factors on Carbon Stocks of U.S. National Forests

General Technical Report RMRS-GTR-402

Appendix 11: Alaska Region, Individual Forests

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Abstract: This report assesses how carbon stocks at regional scales and in individual national forests are affected by factors such as timber harvesting, natural disturbances, climate variability, increasing atmospheric carbon dioxide concentrations, and nitrogen deposition. Previous baseline assessments of carbon stocks (<https://www.fs.fed.us/managing-land/sc/carbon>) evaluated observed trends based on forest inventory data but were limited in ability to reveal detailed causes of these trends. The expanded assessments reported here are based on an extensive disturbance and climate history for each national forest, and two forest carbon models, to estimate the relative impacts of disturbance (e.g., fires, harvests, insect outbreaks, disease) and nondisturbance factors (climate, carbon dioxide concentrations, nitrogen deposition). Results are summarized for each region of the National Forest System in the main document. A set of appendixes ([available online](#)) provides more detailed information about individual national forests within each region. Results are highly variable across the United States. Generally, carbon stocks are increasing in forests of the eastern United States as these forests continue to recover and grow older after higher historical harvesting rates and periods of nonforest land use. In contrast, carbon stocks in forests of the western United States may be either increasing or decreasing, depending on recent effects of natural disturbances and climate change. The information supports national forest units in assessing carbon stocks, quantifying carbon outcomes of broad forest management strategies and planning, and meeting carbon assessment requirements of the [2012 Planning Rule and directives](#). Results of these expanded assessments will provide context for project-level decisions, separated from the effects of factors that are beyond land managers' control.

Keywords: forest carbon stock, national forest, land management, natural disturbance, climate change

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1. Disturbance trends

Disturbance records were summarized by type (fire, harvest, wind, and insects) and by magnitude in Figure 1.1 a-b. Disturbance in the Chugach was extremely rare, and affected relatively little area. Harvest dominated the disturbance regime of the Tongass, although also at a low level. The Tongass also saw storm damage and insect activity at the end of the observation period.

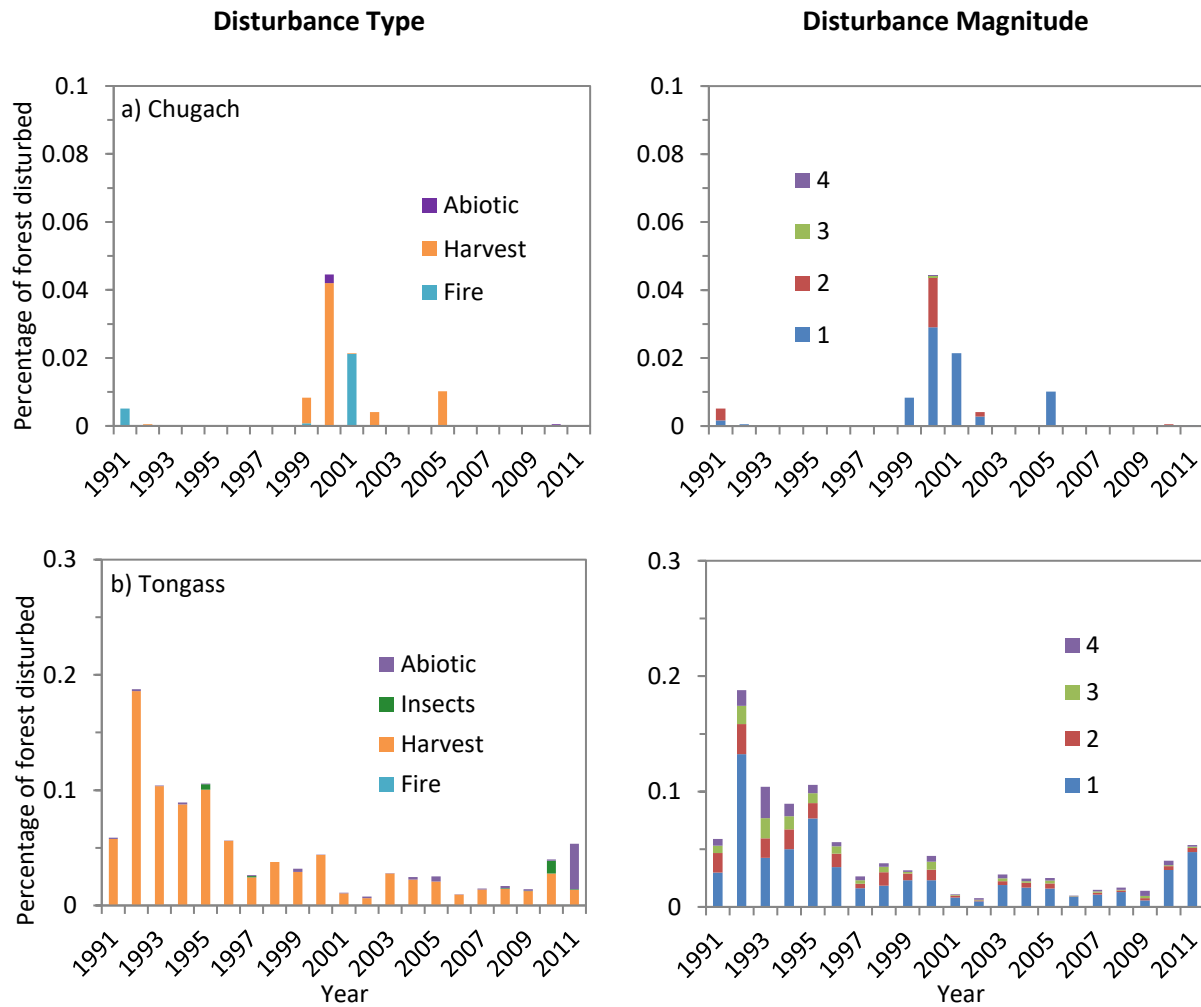


Figure 1.1. Annual rates of disturbance in the Alaska Region, mapped using visual interpretation of several independent datasets and summarized as the percentage of the forested area disturbed from 1991 through 2011 by (a) disturbance types including fire, harvests, insects, and abiotic; and b) magnitude classes, characterized by percentage change in canopy cover (CC) and categorized as follows: (1) 0 to 25 percent CC, (2) 25 to 50 percent CC, (3) 50 to 75 percent CC, and (4) 75 to 100 percent CC.

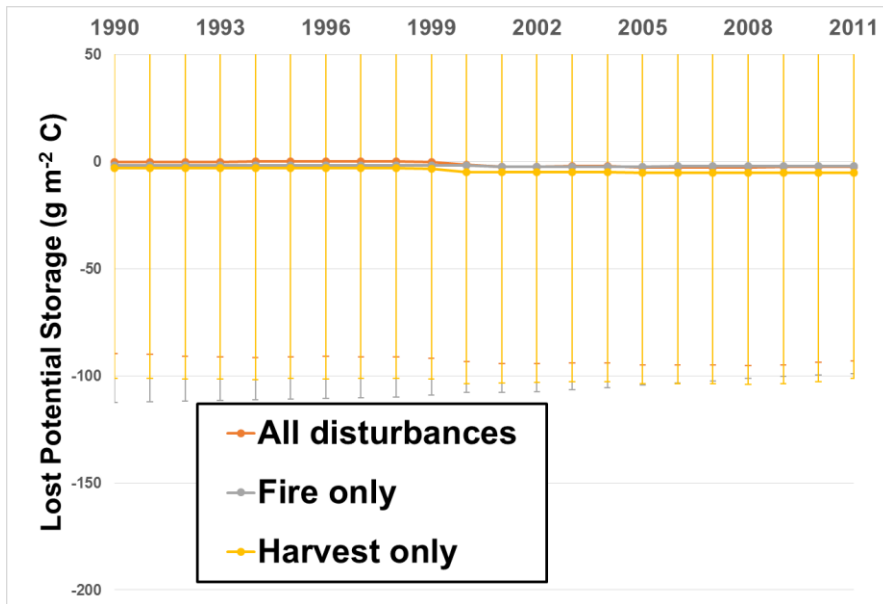
2. Effects of disturbance and management activities (ForCaMF)

ForCaMF uses carbon dynamics derived from the combination of FIA plot data and FVS to interpret the consequences of recorded harvests and natural disturbances. This appendix contains ForCaMF results for the two national forests in the Alaska Region from 1990 to 2011. Figure 2.1 shows the evolution of C impacts resulting from the disturbance patterns shown in Figure 1.1. Units in Figure 2.1 represent reduced C storage per square meter. Error bars around the impact of each type of disturbance represent 95% confidence intervals derived from 500 simulations of all recognized constituent uncertainties, as described earlier. Figure 2.2 summarizes the ForCaMF output shown in Figure 2.1: the pie chart represents the proportional importance of each type of disturbance as measured in 2011 (the last date in Figure 2.1).

As might be expected from the low disturbance levels in Figure 1.1, there was almost no impact of disturbance in the Chugach (Figure 2.1). However, there was some diversity in the few disturbances observed, which is reflected in Figure 2.2. The Tongass National Forest was much less diverse, with harvests accounting for a reduction of approximately 50g/m² less carbon compared to an undisturbed scenario.

Some of the harvest addressed here may have been designed to salvage timber following fire or storm activity. Given the mapping methods used here, it is likely that both the original disturbance and the subsequent harvest were detected and mapped. For purposes of this assessment, losses of C storage potential (Figure 2.1) occurring between the two events (e.g., losses in a fire due to combustion and immediate emission) were assessed to the first process. Salvage operations and subsequent C dynamics were associated with harvests. For managers wishing to assign salvage impacts solely to the original disturbance, this decision within ForCaMF over-stated the impact of harvest.

2.1a) Chugach National Forest



2.1b) Tongass National Forest

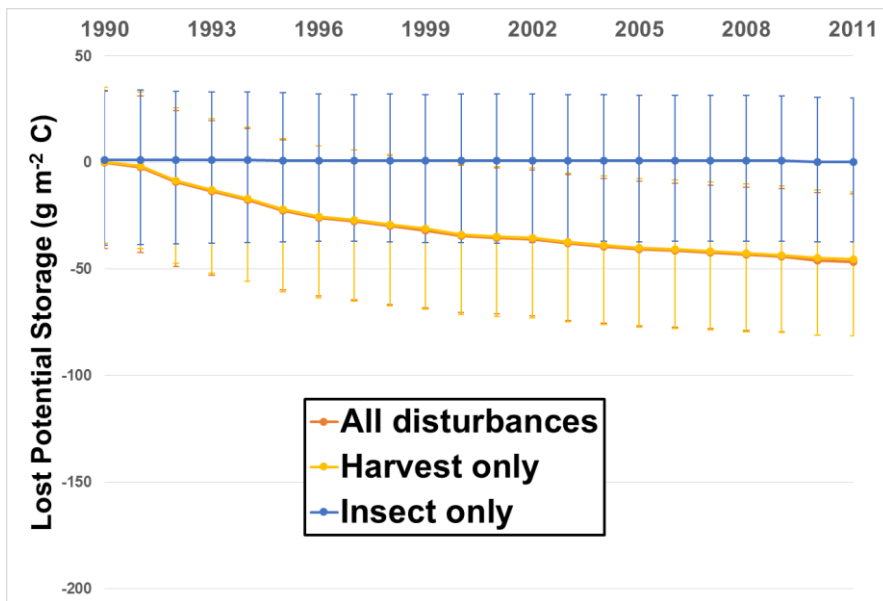
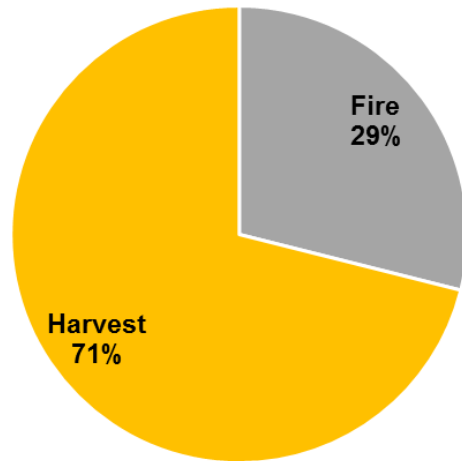


Figure 2.1. The impact of different kinds of disturbance, occurring from 1990 through 2011, on carbon (C) stores in the Alaska Region. The difference in storage for each year is shown between an “undisturbed” scenario and a scenario that includes only observed amounts of the specified type of disturbance. Error bars represent a 95-percent confidence interval; 100 g/m² equals 1 metric tonne (or Mg)/ha.

Effect of Different Disturbances, 1990-2011, on Carbon Storage in Chugach



Effect of Different Disturbances, 1990-2011, on Carbon Storage in Tongass



Figure 2.2b. Proportional effect of different kinds of disturbance on carbon storage in each national forest in the Alaska Region for the period 1990 through 2011.

3. Management implications of ForCaMF results

Earlier baseline assessments (<http://www.fs.fed.us/climatechange/advisor/products.html>) presented inventory-derived estimates of how much carbon is stored in the forests and in the harvested wood product pools of each national forest. The ForCaMF analyses here focused on how different types and intensities of disturbance have influenced those stocks in recent decades. Specifically, results given in Section 6.9 of the main report and previous sections of this appendix provide details about: 1) patterns of disturbance; 2) how disturbance impacts on C storage evolved in each forest from 1990 to 2011, and; 3) the level of uncertainty associated with assessments of each forest. In this section, we bring this information together to answer the simple questions of: “How much do disturbances really disrupt C storage?” and “which disturbance processes in each forest are the most important?”

In highlighting what information managers and planners can gain from these analyses, it is useful to remember that C storage is simply one ecological service, among many, that forests provide. That service mitigates the climate impacts of greenhouse gases emitted through the use of fossil fuels by removing carbon dioxide (CO₂) from the atmosphere. Figure 3.1 shows how much less C (by percentage) was stored in each forest in 2011 because of different types of disturbance since 1990. Disturbance patterns continue to change, but this assessment of the recent past represents the best available insight into how sensitive National Forest C storage is to fire, harvest, insects, disease, and weather events. Residual disturbance effects (*e.g.*, decaying dead C) of monitored events will depress C storage for many years after 2011, just as many pre-1990 disturbances continue to affect current stocks. In most cases, forests re-grow after disturbance and become C sinks for many decades or centuries after a relatively short period of reduced C stocks. In some regions where C stocks have reached elevated levels because of disturbance suppression, a lower level of C stock may be more sustainable compared with the recent past.

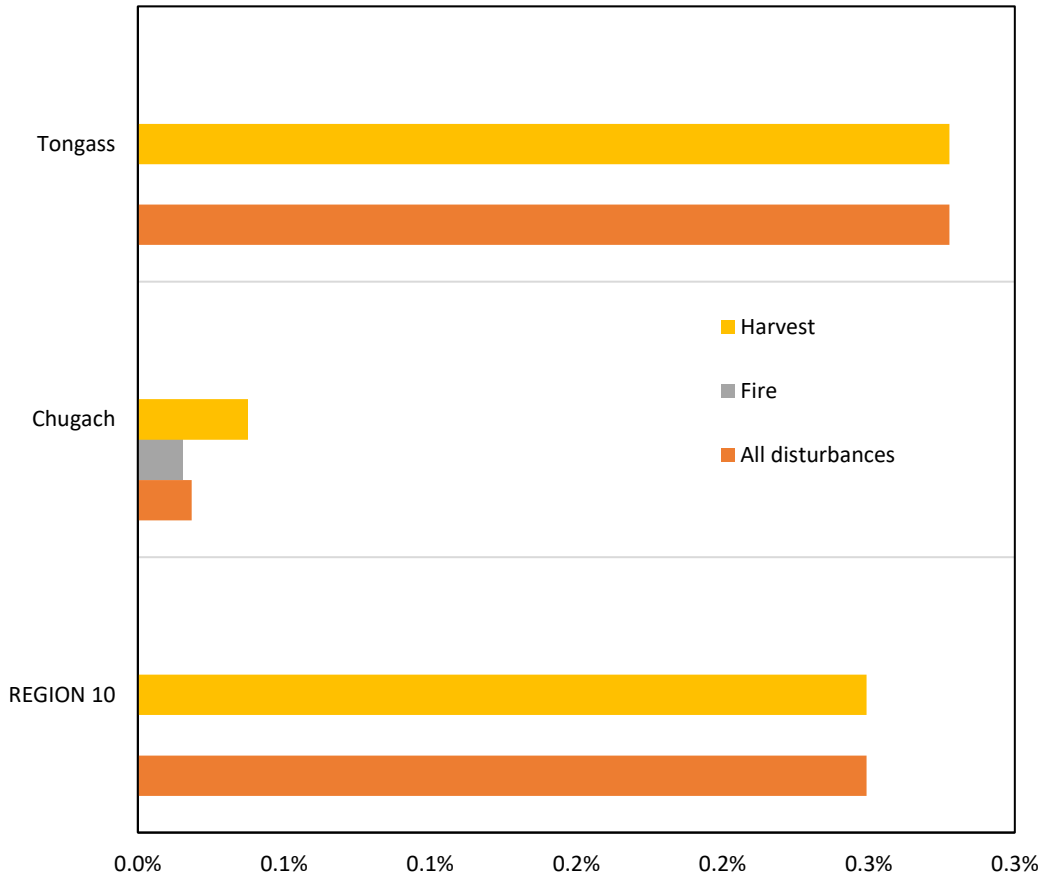
The period of this snapshot was somewhat arbitrary; however, every analysis needs sideboards, and the period used here coincides with our best monitoring data (satellite imagery, Agency activity records, FIA data). The percentages recorded in Figure 3.1 may seem relatively small, but they often represent very large amounts of climate mitigation benefit. For instance, if a National Forest has half a million hectares of forestland that FIA tells us is storing 50 Mg of C per hectare, and ForCaMF tells us that there would be 2% more C without insect activity from 1990-2011, that is a difference of half a million metric tonnes (Mg) of C, or 1.835 million tonnes of CO₂ (using a 3.67 conversion ratio for C to CO₂). For perspective, this is approximately the amount of CO₂ released by burning around 200 million gallons of gasoline (US Energy Information Administration), and its offset value (amount it would be worth if its continued storage were sold on an open market at a conservative price of \$10/tonne) would be almost \$20 million.

There are certain ways that Figure 3.1 does not tell the complete story. The FVS model, which supplies stand dynamics within ForCaMF, does not cover soil organic C, and Figure 3.1’s calculations exclude soils. Fortunately, the InTEC model presented in this assessment do provide insight into soil C dynamics. More importantly, there are some types of disturbance known to be important that were excluded. For instance, root diseases are known to be prevalent in many parts of the country, but they can be difficult to detect with satellite or aerial imagery because their effects in most years can be limited to reduced growth and suppression of regeneration. ForCaMF was used to assess the impacts of root disease in only 6 national forests, all in the Northern Region. That analysis, which was only possible because of a specialized “regional add-on” variable to core FIA measurements, showed significant root disease impacts that equaled the impacts of fire despite several large fire events in the Region (Healey et al., 2016). We know that we are missing similar processes across the country that are not well addressed by available monitoring data.

Disturbances due to climate variability were assessed with the InTEC model which includes precipitation and temperature as major factors affecting forest processes. The effects of climate variability may be positive or negative, and are often highly variable from year to year, depending on the region and how the climate variables interact to affect photosynthesis and respiration. The effects of climate also interact with other atmospheric changes particularly increasing atmospheric CO₂ concentration and nitrogen deposition, both of which typically enhance growth rates of forests.

Lastly, this assessment does not consider storage of harvested C in product pools. Conversion of forest material to durable wood products defers emissions of the associated C until decay or combustion occurs following disposal. Earlier baseline assessments and assessments by Stockmann et al. (2012) quantified C stocks in wood products that remain in use or landfills, and work is ongoing to combine ForCaMF and product C dynamics models. In the present assessment, however, harvest effects (like the effects of all disturbances) are restricted to ecosystem stocks, a limitation that overstates the emissions of CO₂ from harvest from an atmospheric point of view. The effect of substituting wood products for other materials such as concrete and aluminum are not considered in any of the assessments but are potentially significant and will be assessed in future work.

It is outside the scope of this assessment to suggest the importance of ecosystem services associated with C relative to other values such as water yield or habitat conservation. What we do provide is tangible information about how management and disturbance prevention/suppression can impact (and has impacted) the climate change mitigation a national forest generates. To the degree planners value C storage as a service, the disturbance rates published here, along with resultant C storage differences, can frame management goals moving forward.



2011 Carbon Storage Reduction due to 1990-2011 Disturbances

Figure 3.1. Carbon stock reduction in 2011 due to disturbances occurring from 1990 through 2011, by each national forest and for all national forests combined in the Alaska Region. Percent reduction represents how much nonsoil carbon was lost from the baseline forest inventory carbon stock estimates.

4. Effects of disturbance, management, and environmental factors (InTEC)

The InTEC model was not applied to the national forests in Alaska.