Manti – La Sal
National Forest Plan Revision
Assessments

Topic 4 – Carbon Stocks

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for:

The Manti – La Sal National Forest

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Topic 4- Carbon Stocks

In the U.S., 81 percent of total greenhouse gas emissions come from carbon dioxide (figure 1). Carbon dioxide is removed from the atmosphere, or sequestered, when it is absorbed by plants as part of the biological carbon cycle. In 2014 U.S. greenhouse gas emissions totaled 6,870 million metric tonnes and continue rising. Within the same year Land Use and Forestry were responsible for offsetting 11.5 percent of those emissions (EPA 2016). The National Forest System holds 24 percent of the total carbon stocks in the United States, excluding interior Alaska (USDA 2015). The ability of forestland to absorb and store carbon from the atmosphere can play a significant role in managing current levels of atmospheric carbon dioxide.

Figure 1. U.S. Greenhouse Emissions in 2014

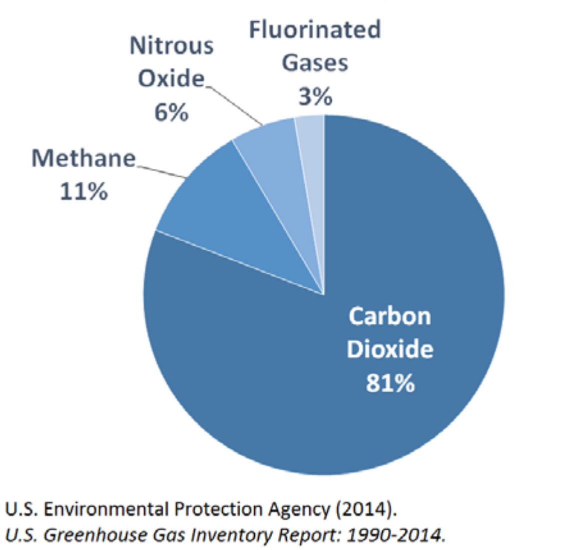


Figure 2. U.S. Carbon Dioxide Emissions

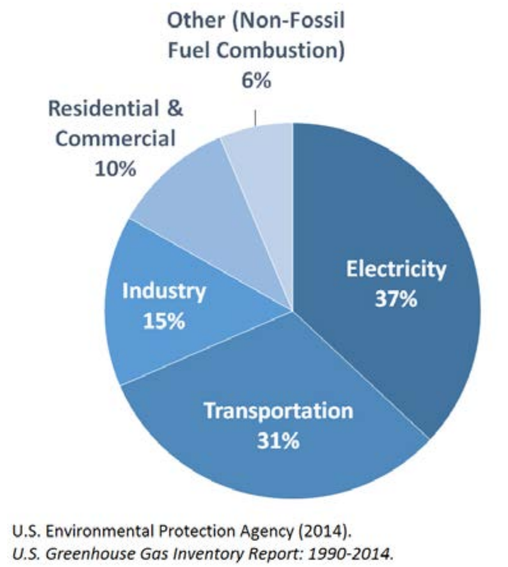


Figure 3. Representation of the carbon cycle

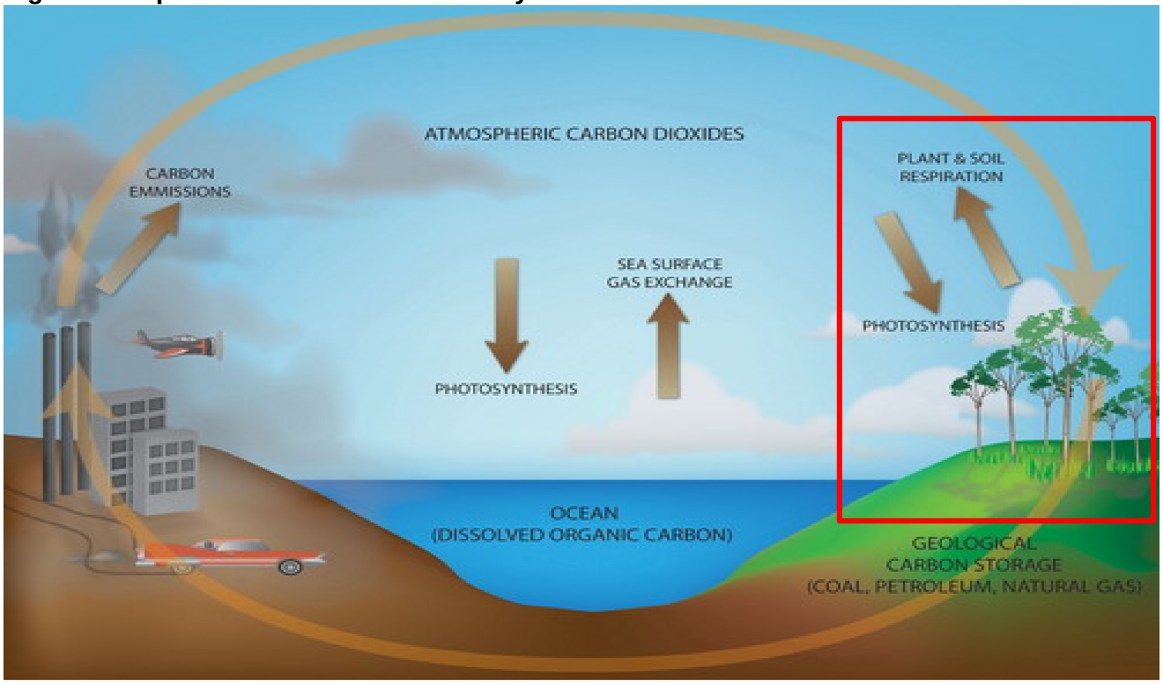


Figure 3 is a simplified representation of the global carbon cycle, within which there are four main carbon reservoirs: the ocean, the atmosphere, the geosphere and the biosphere. This report will focus on carbon in living and dead terrestrial biomass and soils, or biocarbon, and its exchange with atmospheric carbon, as shown in the red highlighted box of figure 3. Terms and definitions relating to the carbon cycle are listed below (Woodall et.al. 2015).

Pool: A reservoir or system which has the capacity to accumulate or release carbon (USDA 2015).

Stock: The amount of carbon contained in a volume. Carbon stocks are dynamic and fluctuate over time as a natural result of the carbon cycle, and from disturbances such as wildfire, timber harvest, insect damage, climate change, and land management (USDA 2015).

Sequestration: When carbon dioxide is removed from the atmosphere and absorbed by plants as part of the biological carbon cycle (USDA 2015).

Sink: A land area that sequesters more carbon dioxide from the atmosphere than it emits (USDA 2015).

Source: Any process that releases carbon into the atmosphere (USDA 2015).

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. 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) (USDA 2015).

Scale – Land Type Associations

Spatial Scale: Vegetation types and the Manti-La Sal National Forest boundary.

Temporal Scale: 1993- 2014 the most current data, approximately 21 years.

Indicators

- Carbon sequestration is measured by the amount of biomass the forest has and grows per year. Basically, plants that photosynthesize are sequestering carbon.
- Carbon pools, stocks, storage (carbon sinks)

Forests Stocks	Measure	Rationale
Carbon Pools	Metric tonnes	Forest carbon pools are forest's capacity to store carbon. Pools are live above ground, live below ground, dead wood, Litter, soil organic.
Carbon by Vegetation Community	Metric tonnes	Amount of carbon stored (carbon pools) in the five vegetation communities.
Sequestration	Measure	Rationale
Net Primary Productivity (NPP)	Metric tonnes carbon/acre/year	Measure of a forest's ability to absorb carbon from the atmosphere.
Net Forest Carbon	Mesaure	Rationale
Carbon Stock Change	Teragrams carbon per year	Assessing movement of forest carbon between stocks

Existing Condition

Carbon Pools, Stocks, Stores and Sinks:

Most of the earth's carbon is stored in rocks (Ajani et.al. 2013). Coal is one of the biggest carbon stocks on the Forest. Coal mining has occurred on the Wasatch Plateau for well over 100 years. From the late 1800s to 2015, 722.3 million short tons of coal have been removed from the Plateau (UGS 2016). In

2015, 78 percent of Utah's coal production came from Carbon and Sevier Counties. Beginning in 2008 coal production began to decline. In 2015 the Deer Creek Mine closed. Based on the current and projected stores, there is still 1.2 billion short tons of coal reserves on the Wasatch Plateau (UGS 2016).

Figure 4. The proportion of the five carbon pools on The Manti-La Sal National Forest (USDA 2016b FIA data 2014)

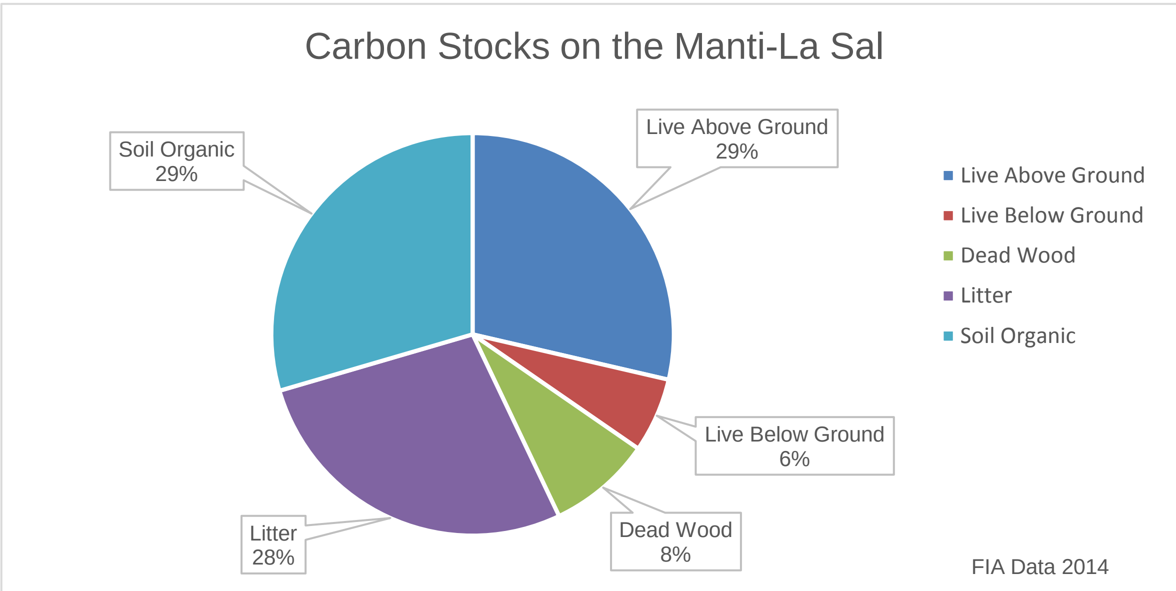
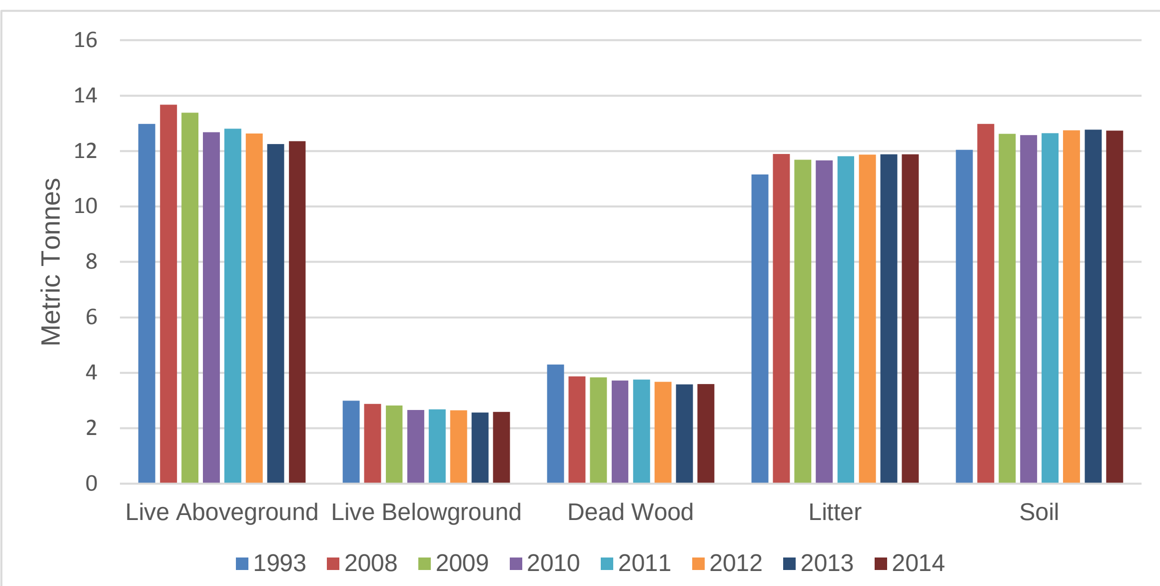


Figure 4 is the proportions of surface carbon stocks found on the Manti-La Sal National Forest. The USDA Forest Inventory and Analysis (FIA) program has collected data categorized in five different surface ecosystem pools: live above ground, live below ground, dead wood, litter, and soil. All the vegetation types are included in the five pools.

Figure 5. Trend of five carbon pools (USDA 2016b FIA data 1993-2014)



Pool 1 - Live above ground: all live biomass from understory to the tops of trees (e.g. grasses, forbs, shrubs, and trees). This is currently the largest carbon pool on the forest. Harvest, disturbance, and decay can reduce this pool. Conversely, regenerating vegetation can increase it (Woodall et.al.2015).

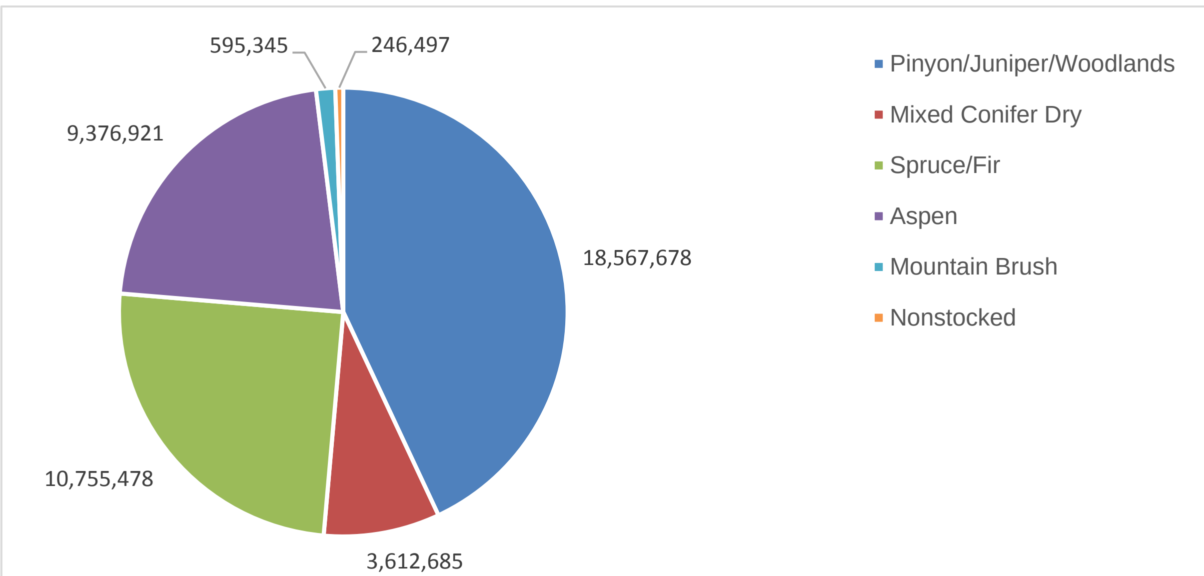
Pool 2 - Live below ground: carbon in coarse roots of live trees, saplings, and understory vegetation. Below ground carbon stocks are proportionately less than above ground stocks due to the amount of biomass (Woodall et.al.2015).

Pool 3 - Dead wood: standing wood and down wood greater than 3 inches in diameter. This includes the stumps and roots. As dead wood decays or is removed from the forest this pool can decline. Additionally, as trees are masticated or consumed by fire carbon may transfer into the Litter pool or be released into the atmosphere (Woodall et.al. 2015).

Pool 4 - Litter: includes duff (i.e. organic material on the floor of the forest, fine woody debris and fine roots in the organic forest floor layer above mineral soil), humus, foliage, and twigs less than 3 inches in diameter. Due to recent beetle epidemics, fire, disease, and increasing amount of wood being harvested, carbon stock in the litter pool has increased (Woodall et.al. 2015).

Pool 5 - Soil: this pool includes carbon in fine organic material below the soil surface to a depth of 1 meter (Woodall et.al. 2015).

Figure 6. Carbon stocks by vegetation types on the Manti-La Sal National Forest in metric tonnes (USDA 2016b FIA data 2014)



Pinyon/Juniper/Woodlands: This type contains the highest acreage of any vegetation type and holds 43 percent of the Forest's carbon because of the large pinyon pine, juniper and gambel oak populations.

Forested: includes aspen, spruce fir and mixed conifer vegetation types. 55 percent of the forest's carbon stocks are in forested vegetation. The forested group contains the largest trees on the forest and consequently larger volumes of carbon storage, even though the collective acreage is less than woodlands.

Non-stocked: is the combination of perennial forbs, grasslands, sagebrush, and alpine vegetation types. The non-stocked vegetation types are widespread across the forest however, store a relatively small amount of carbon.

Stressors Affecting Carbon

Figure 7. Percentage of forest affected by Disturbance types (USDA 2016c)

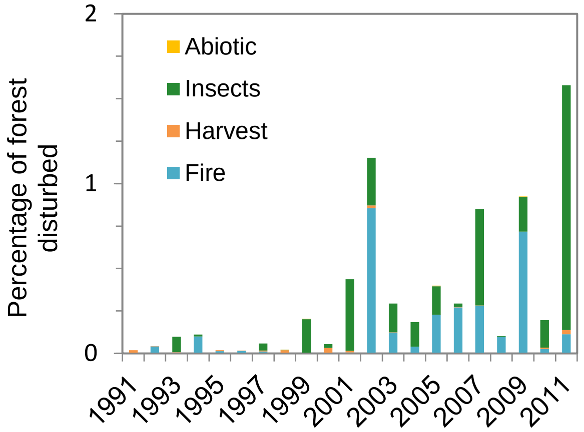


Figure 8. Disturbances by magnitude effecting canopy cover (USDA 2016c)

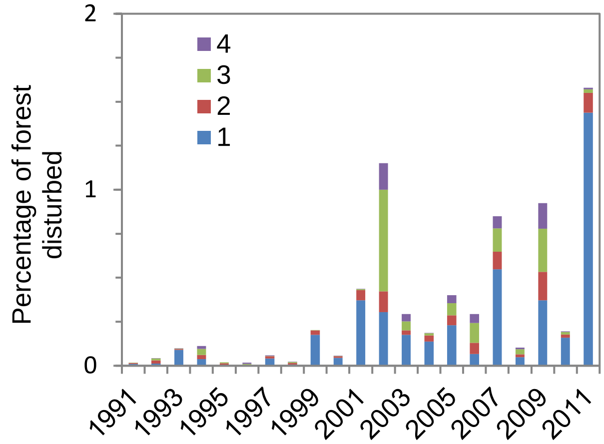


Figure 9. Proportional effect of disturbances on carbon storage (USDA 2016c)

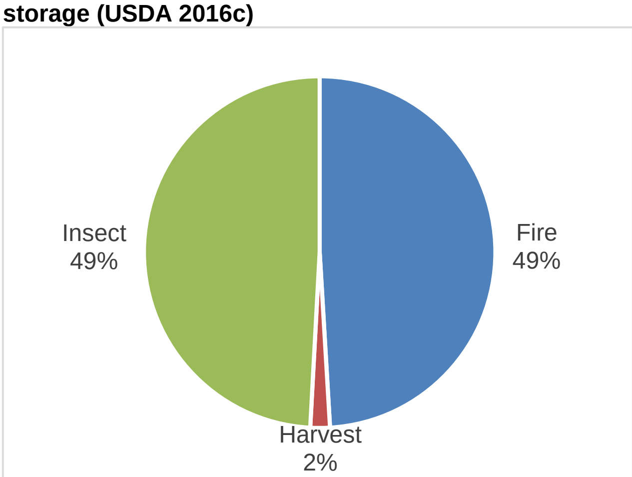
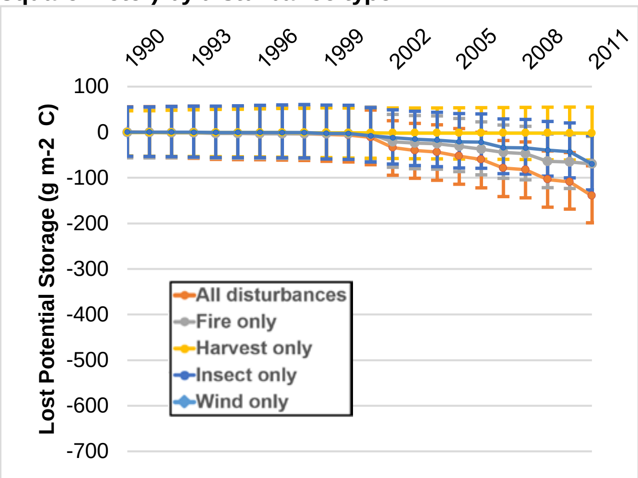


Figure 7 includes insects, fire, harvests and abiotic disturbances. Figure 8 shows Percentage of the forest disturbed by magnitude class, characterized by the percentage of change in canopy cover (CC) and categorized as follows:

1) 0-25% CC (e.g. moderate fire torching)
2) 25-50% CC (e.g. endemic insect and disease)
3) 50-75% CC (e.g. epidemic insect and disease)
4) 75-100% CC (e.g. high severity stand replacing fire)

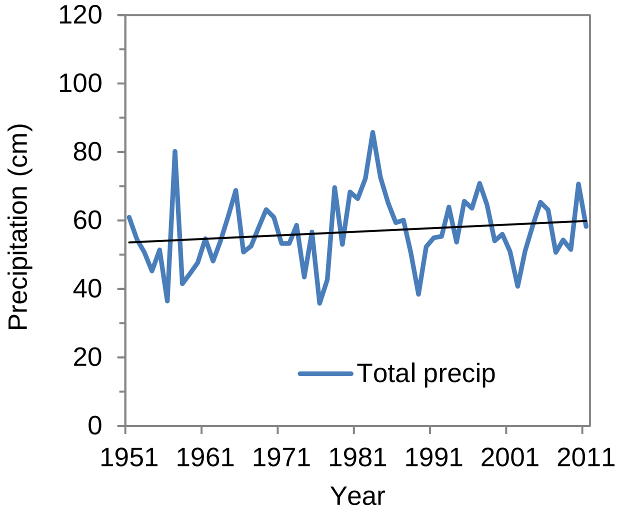
Category 4 magnitude distrubances would likely have the greatest effect to forest carbon emmisions and sequestration. Figure 9 shows the proportion of disturbances on the forest. Insects and fire have the biggest effects to vegetation.

Figure 10. Reduced carbon storage (in grams per square meter) by disturbance type



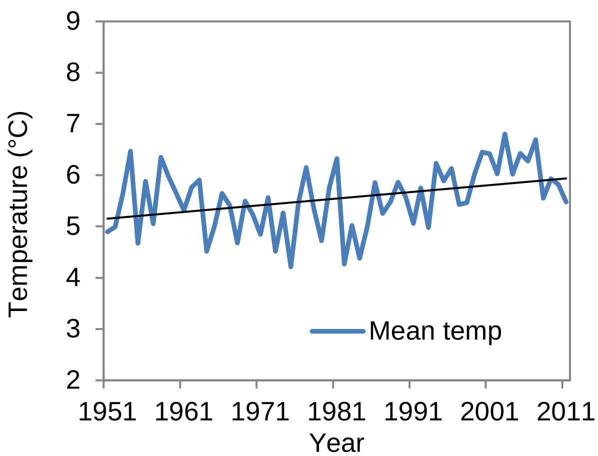
Model of lost potential carbon storage (in grams per square meter) as a result of biomass reduction due to fire, insect, harvest, and disease for 1990 – 2011 (USDA 2016). Fire has had the biggest effect followed closely by insect and disease. As of 2011, due to all disturbances combined the Manti-La Sal has lost 140 grams of potential carbon storage per square meter. It must be emphasized that there is a residual effect for almost every disturbance because impact is being compared to what would happen to carbon storage if the stand had remained undisturbed. The model accounts for gradual decay of fire or insect-killed material, so net carbon storage will likely continue to diverge from the undisturbed scenario for several years. This explains the fact that the effects of fire can increase even in years when those events do not occur.

Figure 11. Annual precipitation in centimeters (USDA 2016c)



These are annual averages and do not represent monthly or seasonal patterns. Climate patterns specifically during the growing season are what have a significant effect on carbon stock change. Drier climate during the growing season limits growth and consequently carbon sequestration (USDA 2016a). As a general rule of thumb as precipitation decreases vegetation growth declines and therefore affects the ability of a forest to sequester carbon.

Figure 12. Temperature in celsius (USDA 2016c)



These are annual averages and do not represent monthly or seasonal patterns. Climate patterns specifically during the growing season are what have a significant effect on carbon stock change. Warmer temperatures encourage decomposition and decay which increases respiration/carbon emission from the forest, in addition to encouraging drought (USDA 2016a). This trajectory may cause the Manti-La Sal to become a future carbon source. Increasing temperature combined with decreasing precipitation can have substantial effects to vegetation growth. As a result reduce vegetation production reduces the forests ability to sequester and store carbon.

Trends

Figure 13. Relationship between net primary productivity and stand age for each forest type (in metric tonnes of carbon per acres per year) (USDA 2016c).

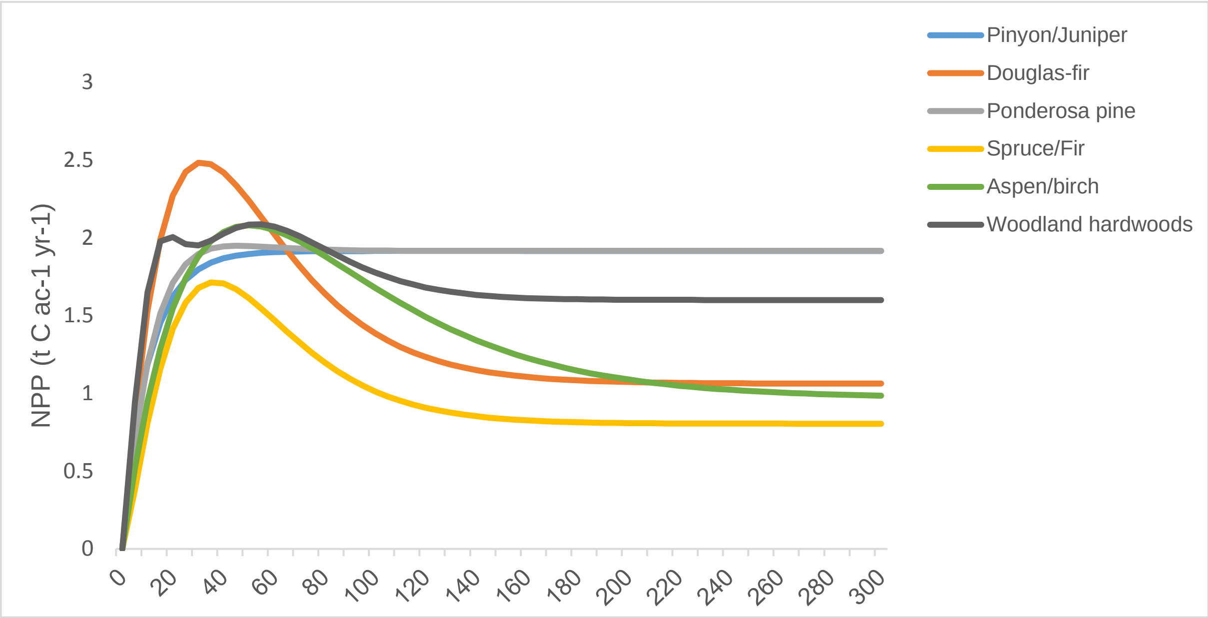
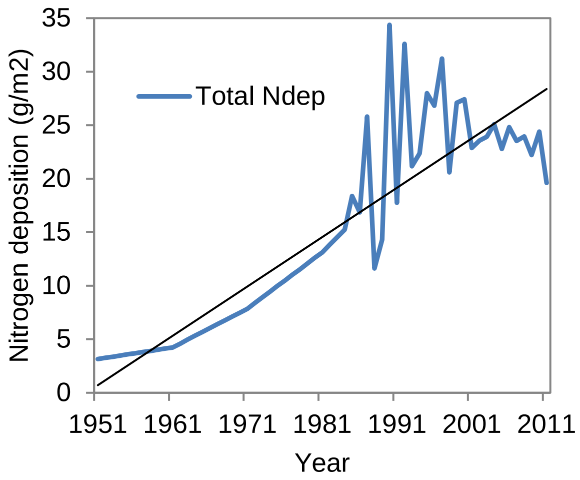


Figure 13 shows a forest's rate of sequestering carbon is higher when vegetation is relatively young (10-50 years) because of its need for nutrients to support growth. Peak sequestration differs among different forest types and levels out with maturity. NPP is the difference between the production of chemical energy which mainly occurs through photosynthesis and autotrophic respiration, indicating the rate of carbon uptake by a forest's biomass. Forest NPP will change predictably with stand age but is influenced by climate conditions and forest management (He et. al. 2012).

Figure 14. Total nitrogen depostion in grams per square meter (USDA 2016c)



Data was not collected prior to 1985 and estimates were extrapolated through modelling.

Atmospheric nitrogen occurs mainly as a result of fossil-fuel combustion and agricultural fertilizer use and is deposited through precipitation. High levels of nitrogen deposition can by harmful but small additions can be beneficial because it assists CO2 uptake (photosynthesis) from the atmosphere (Law 2013).

Forests in the west (e.g. Manti-La Sal National Forest) respond by increased growth of trees from increased nitrogen. Upward trend from the late 1950s is from anthropogenic (human-caused) effects (Law 2013).

Figure 15. Carbon stock change in teragrams of carbon per year (USDA 2016c)

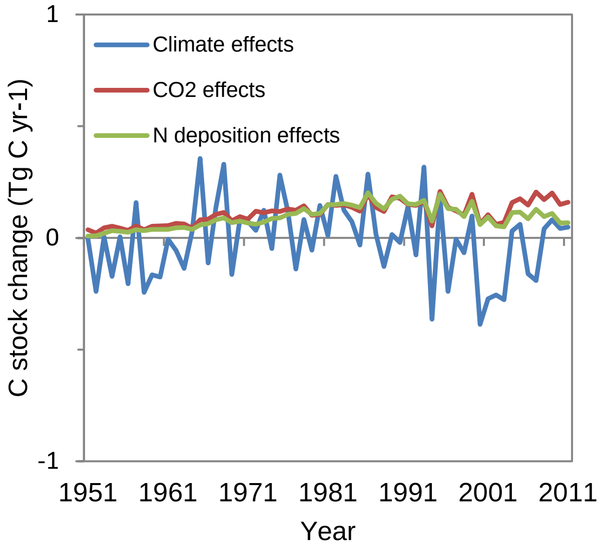
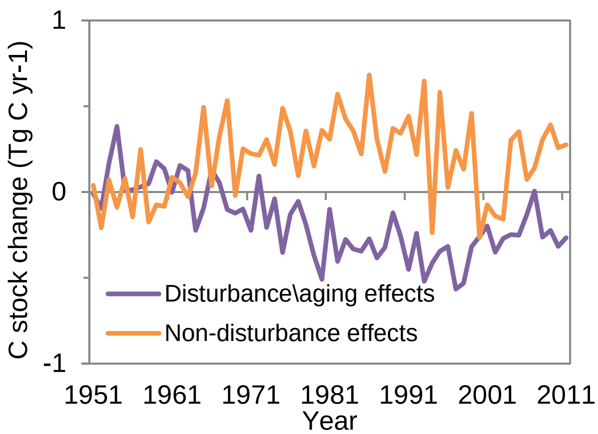


Figure 15 shows the changes in carbon stocks between forest and atmosphere due to individual non-disturbance factors including climate variability, atmospheric CO_2 concentration, and nitrogen deposition. Positive values represent carbon sinks from the atmosphere, whereas negative values represent carbon sources to the atmosphere. Nitrogen, CO2, and Climate interact with each other, which in turn effects tree growth –

1) Positive spikes on the graph are a result in tree growth. Increased growth comes from increased nitrogen, wet years, and cooler temperatures.
2) Negative spikes are a result of drought, reduced precipitation, and increasing temperature.

Nitrogen and CO2 have low variability whereas climate is much more volatile due to inter annual climate patterns (i.e. seasonal temperature shifts, spring runoff, etc…)

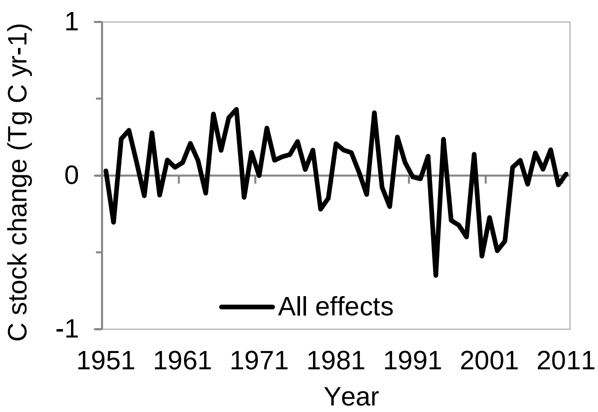
Figure 16. Summary carbon stock change in teragrams of carbon per year (USDA2016c)



All disturbance factors (fire, harvest, insects as well as regrowth and aging) and the sum of all non-disturbance factors (see figure 15 climate effects, CO2 and Nitrogen deposition) combined. Positive values represent C sinks from the atmosphere or enhancement effects, and represent forest regeneration or years of increased growth. Negative values represent C sources to the atmosphere, and are a result of low productivity aging decadent stands, or disturbances killing or removing vegetation.

Disturbance and aging effects on stands on the forest have had the most negative impacts when sequestering carbon.

Figure 17. Carbon stock change due to all effects interagrams of carbon per year (USDA2016c)



All factors combined, which is the sum of disturbance\aging and non-disturbance effects.

Figure 17 is the sum of effects in figure 16. Some large-scale high-severity fires and insects and disease disturbances occurring in the late 90s have resulted in carbon emissions. Overall, over the past 60 years (for this dataset) the forest has been neither a carbon sink nor source but been relatively stable. Positive values represent C sinks from the atmosphere or enhancement effects, whereas negative values represent C sources to the atmosphere, or detraction effects.

Figure 18. Accumulated carbon in teragrams (USDA 2016c)

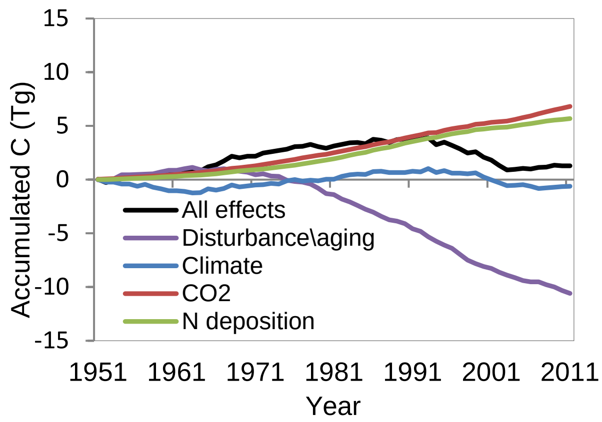


Figure 18 is the accumulated C due to individual disturbance\aging and non-disturbance factors, and all factors combined from 1951-2011 (excluding C accumulated pre-1951). At any given year between 1951 and 2011 accumulated carbon is shown.

Example: if in 1951 accumulated CO2 was 0.3, in 1952 0.2 total would be 0.3 + 0.2 =0.5.

N deposition and CO2 are consistently increasing, climate being relatively stable, and disturbance emitting carbon, the forest is overall sequestering more carbon than it emits

Figure 19. Carbon emissions due to disturbance in teragrams per year (USDA 2016c)

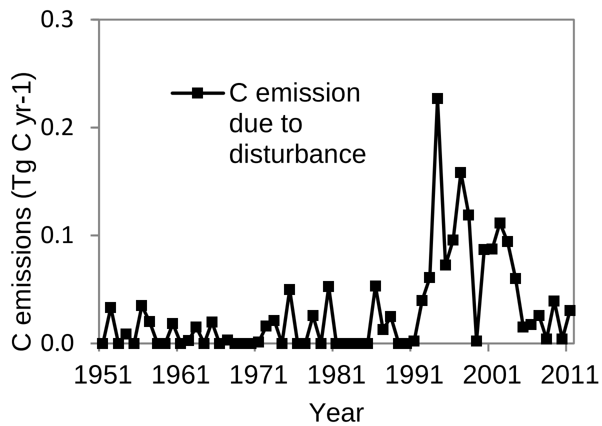


Figure 19 results were modeled based on stand age (i.e. disturbances that would reset any given stand to zero). So even though the graph shows zero in 1982-85 the forest still in reality created emissions. In general, this graph shows the Forest's greatest emissions of carbon were from the spruce bark beetle (Scottorn 2016) and large-scale stand-replacing fires (Bigelow 2016) occurring in this timeframe. Basically, when vegetation is removed, a forest's ability to sequester and store carbon is reduced.

Data Gaps

Lack of long term data trends, carbon sequestration and climate are topics being

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APPENDIX A.

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.

Multiple	Name	Symbol	Conversion	Name	Symbol
	grams	g	x1,000,000	metric tonne	t
	meter square	m^2	x1000	hectare	ha
	metric tonne	t	x1.10231	short ton	US t
	metric tonne	t	x1	megagram (10^6)	Mg
	megatonne (10^6)	Mt	x1	teragram (10^{12})	Tg
	hectare	ha	x 0.404685	acre	ac
	centimeter	cm	x2.54	inch	in