Baseline Carbon Assessment—Carson National Forest

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Introduction

The emission of greenhouse gases (GHGs) by human activities and natural processes contribute to the warming of the Earth's climate. Warming could have significant ecological, economic, and social impacts at regional and global scales (IPCC 2007). In 2005, US forests were estimated to be sequestering nearly 220.5 million tons of carbon (Cameron et al. 2003), to suggest that forests and woodlands of the Southwest could have a significant role to play in the sequestration of carbon and climate change mitigation. The US Forest Service has directed a baseline assessment of carbon stocks as part of the forest plan assessment process (36 CFR 219.6(b)(4)).

In the following paper we consider the major carbon components of Southwest ecosystems including biomass, carbon emissions, and soil organic carbon. Some estimates are provided for biomass and soil carbon on the Carson NF in northern New Mexico. For the moment, the carbon emissions component has been characterized by using a case study synthesis from the Apache-Sitgreaves NF. We acknowledge that the description of other carbon components, such as forest products, would provide a fuller accounting of carbon stocks and flux; for the time being, inclusion of the major components of biomass, emissions, and soil carbon will suffice for strategic purposes of Forest planning.

Carbon Stocks on the Carson NF

Biomass (vegetative carbon)

Vegetative biomass serves an integral component in forest carbon cycles. Forest vegetation, through the process of photosynthesis, converts atmospheric carbon dioxide to carbohydrates (referred to as carbon fixation). These carbohydrates (sugars) are used by plants to grow both aboveground biomass in the form of stems and leaves, and belowground biomass in the form of roots and tubers. Conversely, through the process of decay, dead plant material slowly releases carbon into the atmosphere as it decomposes. Total carbon stored in vegetative biomass is referred to as the biomass carbon stock, and this is a value that changes through time. The primary influences on biomass carbon stock are plant growth (primary productivity) which serves to increase biomass carbon stock, decay/decomposition which slowly decreases biomass carbon stock, and disturbance in the form of fire and harvest. Wildland fire provides a major source of carbon emissions in a forest setting, and is discussed in detail in the carbon emissions section of this document. Biomass harvest plays a varying role in carbon emissions, depending largely on the use of the wood products. For example, wood products utilized as saw timber in construction tends to provide long term carbon storage with slow release, while wood products used as fuelwood and burned for heat/energy provide increased carbon emissions into the atmosphere. As forest and grassland ecosystems are constantly changing through natural succession and disturbance, biomass carbon stock also changes through time. This section will focus on biomass carbon stocks over time on lands of the Carson National Forest (NF). For the purpose of this section, biomass carbon stock includes aboveground live biomass, standing dead biomass, downed woody debris, litter/duff, and belowground live biomass (belowground nonliving plant material is considered in soil organic carbon). The methods for deriving biomass values for seral states within forest and woodland ecosystems are included in Appendix 1.

Current Conditions: Biomass Carbon Quantities

The Carson NF can be stratified into eight major ecosystem types referred to as Ecological Response Units or ERUs (Table 1). The Forest has several minor types, including two ecosystems listed in Table 1 – 'Alpine and Tundra' and 'Bristlecone Pine'. Each ERU contributes differently to carbon stocks and their flux based on its spatial extent, vegetative community composition and structure, and ecosystem dynamics. Generally speaking, relative contributions to carbon stocks are lowest in grassland ERUs, with increasing contributions by shrubland, woodland, and forest ERUs, respectively.

Table 1. Major ERUs on the Carson NF in acres and percent.

ERU	System Type	ERU Code	Acres	Percent
Alpine and Tundra	Shrubland/Grassland	ALP	9,564	0.6%
Montane/Subalpine Grassland	Grassland	MSG	125,340	8.3%
Bristlecone Pine	Forest	BP	2,754	0.2%
Spruce-Fir Forest	Forest	SFF	289,927	19.2%
Mixed Conifer w/ Aspen	Forest	MCW	130,944	8.7%
Mixed Conifer - Frequent Fire	Forest	MCD	182,834	12.1%
Ponderosa Pine Forest	Forest	PPF	312,840	20.7%
PJ Woodland	Woodland	PJO	178,064	11.8%
PJ Sagebrush	Woodland	PJS	217,198	14.4%
Sagebrush	Shrubland	SAGE	58,935	3.9%
Totals			1,508,401	100.0%

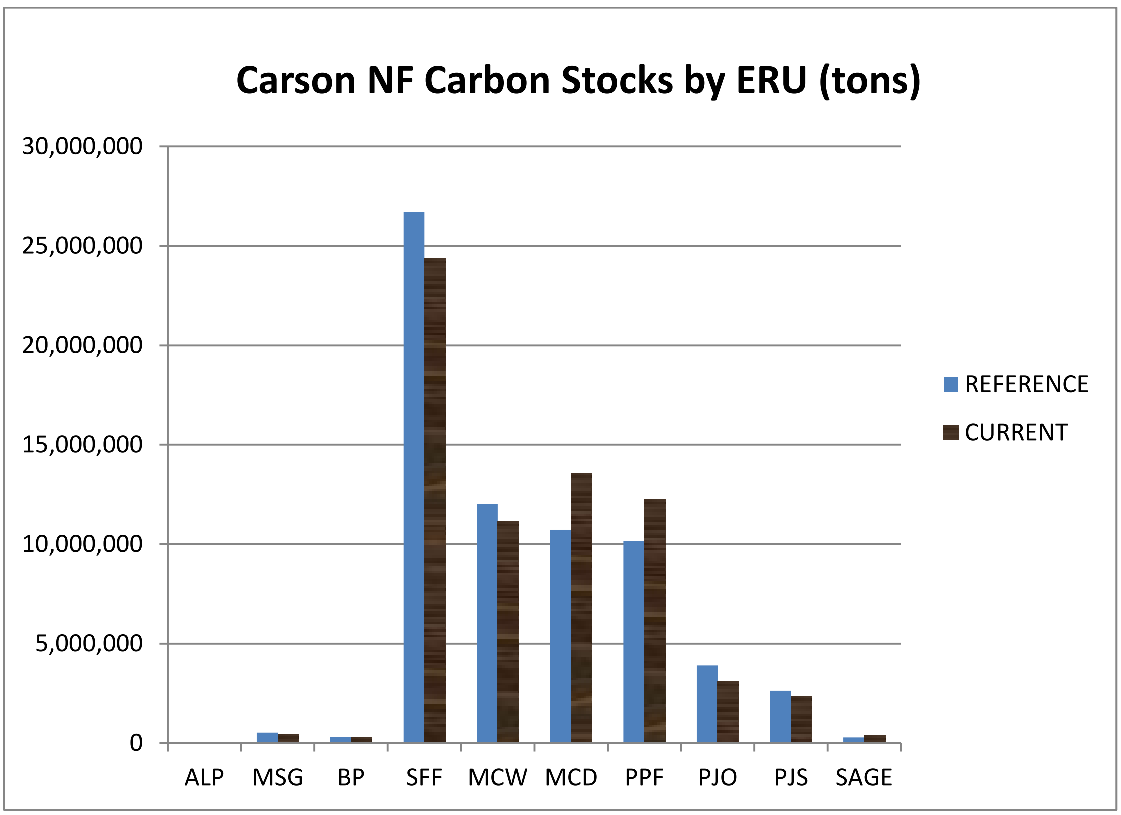
The figures and tables presented in this section represent carbon stock for current conditions, reference conditions, and for select ERUs, modeled future conditions under current management intensities. We will refer to each ERU by its assigned three- to four-letter code; for reference, these appear in the third column of Table 1. Carbon stock values are presented below both by ERU and collectively for the Carson NF. As we will demonstrate below, the current Forest carbon stock overall is about 102% of that present in reference (historic) conditions. While this increase suggests little change over reference conditions, a more complete picture can be drawn by looking at relative contributions from individual ERUs. As illustrated in Table 2 and Figure 1, the balance of carbon stock has decreased somewhat in woodland ERUs (PJO and PJS), while also decreasing in two of the forest ERUs (MCW and SFF), and increasing in the other two forest systems (PPF and MCD). Carbon increases coincide with fire-adapted (frequent fire) ecosystems, while decreases are coincident with those systems of low to moderate fire frequency.

Carbon increases in the fire-adapted types are presumably associated land use patterns, including the decades-long policy of fire suppression, and limited harvest of trees in the most recent years and decades. The reduction in woodland biomass may be associated, at least in part, to type conversions (chaining) where much of the overstory had been removed.

Table 2

ERU	Reference Condition (tons)	Current Condition (tons)
ALP	10,416	10,977
MSG	527,864	464,261
BP	301,469	300,950
SFF	26,707,886	24,373,327
MCW	12,025,677	11,134,887
MCD	10,723,927	13,581,735
PPF	10,156,758	12,253,053
PJO	3,908,518	3,090,154
PJS	2,630,871	2,359,935
SAGE	291,474	375,221
Totals	*67,284,860*	*67,944,500*

Figure 1. Relative Biomass Carbon Stock by ERU.



Also of note is the considerable shift in biomass regimes of the MSG and SAGE systems. In MSG, overall carbon has dropped significantly in part due to the decrease in amount of the most productive plant communities, and increases in amount of low-productivity seral stages. The contemporary concentration of carbon in communities encroached by woody vegetation in the last century also represents a significant shift in biomass patterns within MSG. In the SAGE system, the amount of carbon has increased substantially, likely due to land use patterns of fire suppression and herbivory which favors shrub development.

Trends

Many factors will influence future carbon stocks on the Carson NF, and this assessment is in no way a comprehensive accounting of all possible outcomes. Factors such as climate change, fire frequency and severity, and management budgets are all outside the span of control of Carson forest managers, and as such, only broad generalizations on these topics are provided. However, general ecosystem dynamics in southwestern systems are fairly well understood, and provide a good starting point for assessing trends in biomass carbon stocks. Forest and woodland conditions on the Carson NF have been modeled out into the future for most of those ERUs using State and Transition Modeling (STM), and assumptions based on current management and disturbance patterns[1]. This allows the projecting of relative biomass carbon contributions through time for key ERUs (see a full description of process and methodology in (Appendix 1). Using past assumptions of stand development dynamics and management applications for future projections are inherently problematic in light of projected climate changes.

The general pattern of projected biomass carbon stock on the Carson NF (assuming continuation of current management patterns) is for an increase in total carbon storage in nearly all modeled ERUs above current conditions. Figure 2 and Table 3 depict 100-year projections for primary forest and woodland ERUs against current and reference conditions. These projections assume a continuation of current management, and are not reflective of changes in management that may emerge from the Carson's ongoing effort to revise its land management plan. However, these results do provide meaningful trend information with regards to biomass carbon storage in near future.

[1] Modeling was conducted by the Carson National Forest and Region 3 staff, December 2014 – January 2015.

Figure 2. Trends in Carbon Stocks for Major Forest and Woodland ERUs

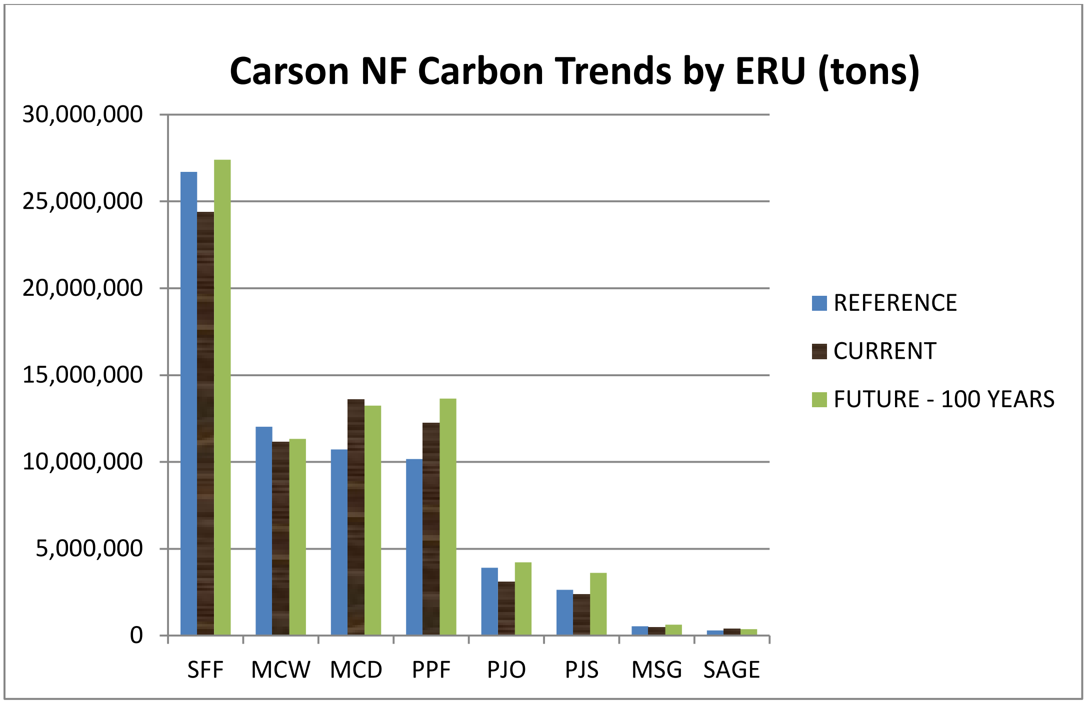


Table 3 Projected Carbon Stocks for Major Forest and Woodland ERUs of the Carson NF

ERU	Current Condition (tons)	Projected +100yrs (tons)	*Projected +100yrs % Change from Current*
MSG	464,261	631,257	36%
SFF	24,373,327	27,397,317	12%
MCW	11,134,887	11,319,335	2%
MCD	13,581,735	13,236,878	-3%
PPF	12,253,053	13,650,315	11%
PJO	3,090,154	4,222,329	37%
PJS	2,359,935	3,617,623	53%
SAGE	375,221	366,993	-2.2%

In all cases except MCD, carbon stocks are projected to increase within the forest and woodland ERUs of the Carson. Results for MCD show a slight decrease. The most substantial increases are in the woodland systems, likely as a consequence of trends in low fire frequency and minimal forest management such as harvest thinning.

Carbon Emissions – Synthesis of Study by Vegh et al. (2013)

Introduction

For the Carson NF assessment, carbon emissions have been characterized below by using a case study synthesis from the Apache-Sitgreaves NFs (Vegh et al. 2013), relevant to forested ecosystems of the Southwest in terms of natural processes and common management activities. The study provides a surrogate solution for emissions assessment in lieu of emissions data and analysis specific to the Carson NF.

Background

To date there has been no binding commitment by the federal government or US Forest Service for the regulation of carbon dioxide (CO_2), though there has been increasing activity at state and regional levels to control carbon emissions to the atmosphere, prompting regulation, voluntary carbon exchanges, and carbon inventory and monitoring programs (Wiedinmyer and Neff 2007). The US Forest Service Planning Rule directs forests to assessment baseline carbon stocks as part of the forest planning process (36 CFR 219.6(b)(4)), and though there are other carbon constituents released in wildfire and prescribed burning, CO_2 is the primary carbon compound and primary greenhouse gas associated with fire emissions (Table 4).

Table 4. Proportion of constituents of wildfire emissions for both greenhouse gases (GHG) and carbon compounds (NRC 2004).

Species	Proportion GHG	Proportion Carbon Constituents
Carbon Dioxide	72.14%	90.82%
Water	21.18%	
Carbon Monoxide	5.57%	7.02%
Atmospheric particulate matter <2.5µ		0.60%
Nitric Oxide	0.39%	
Methane	0.27%	0.34%
Volatile Organic Compounds	0.24%	0.31%
Organic Carbon		0.31%
Non-methane Hydrocarbon	0.20%	0.25%
Particulate Matter > 10µ		0.22%
Particulate Matter <10µ and >2.5µ		0.11%
Elemental Carbon		0.03%
	100.00%	100.00%

Though emissions by fire and other forest processes (e.g., methane from the decomposition of wood) have a relatively minor impact on carbon stocks and flux, atmosphere-based emissions are strongly impacted by biosphere-atmosphere carbon fluxes at regional scales, and represent the carbon component directly involved in the positive feedback of greenhouse gas forcing on climate change. In a given year in the Southwest, carbon emission from fire can exceed fossil fuel emissions at regional scales (Wiedinmyer and Neff 2007). In their study of fire emissions, Wiedinmyer and Neff found that on average carbon emissions were 4–6% of the total anthropogenic emissions for the US. In a separate study, Woodbury et al. (2007) estimated that 10% of total anthropogenic emissions in the US are captured by forest vegetation, to suggest that forests can sequester more carbon than they emit and become an offsetting solution for anthropogenic emissions. The Intergovernmental Panel on Climate Change (IPCC) recognizes the potential for forest and woodland ecosystems, in particular, to perform climate change mitigation (IPCC 2007). In assessing carbon dynamics and emissions in the Southwest, Hurteau and others (e.g., Hurteau et al. 2008, North et al. 2009, Hurteau and North 2010) went further and proposed that large releases of carbon to the atmosphere could be minimized by reducing stand densities. Prior to the Apache-Sitgreaves NF study (presented below), it had been hypothesized, and shown through dynamical modeling and observation (Kobziar et al. 2009, Martinson and Omi 2013, Pollet and Omi 2002), that the reduction of stand densities precludes large pulses of wildfire emissions with a reduction in uncharacteristic fire, such as stand replacement fire in ponderosa pine forests. Preliminary research indicates that the sustainable management of forests, along with careful consideration of byproducts and management residues, would not only balance forest carbon stocks but could also partially mitigate global climate change through increased carbon storage.

Apache-Sitgreaves Study Overview

Recent research on carbon dynamics and emissions related to various conventional forest management activities, focused specifically on the Apache-Sitgreaves (A-S) National Forest in eastern Arizona and western New Mexico, provides surrogate information to guide National Forests of the Southwest in the assessment and management of carbon (Vegh et al. 2013), which we are using here in lieu of more specific analysis of carbon emissions.

A key objective of the A-S study was to determine the long-term (100 years) difference in carbon stocks and carbon emissions between treated and untreated forest ecosystems. While the study was focused on the Ponderosa Pine Forest ERU, the results can be abstracted to other forest and woodland ecosystem types for purposes of characterizing general trends among reference condition, no-action, and treatment scenarios, in terms of 1) fire carbon emissions, 2) total (live and dead) above-ground biomass, and 3) live above-ground biomass. And while the Vegh et al. study did not consider the effects of forest restoration per se (sensu R3 desired conditions), they did evaluate the effects of reduced tree densities on carbon stocks and flux.

Analysis

In their study, Vegh et al. (2013) compare the effects of different management alternatives on overall carbon stocks and emissions. They apply three management alternatives – no action, light thinning, heavy thinning – to determine the overall management effects on carbon sequestration and emissions flux. The researchers used the Forest Vegetation Simulator (FVS) to model stand dynamics over a 100-year simulation and report outcomes for carbon stocks and emissions. For annual treatment in the analysis simulation, all suitable stands on the A-S NF were prioritized in order of the following conditions:

1. Wildland Urban Interface (WUI) areas in high departure plant communities
2. WUI areas in moderate departure plant communities
3. non-WUI areas in high departure plant communities
4. non-WUI areas in moderate departure plant communities
5. WUI areas in low departure plant communities
6. non-WUI areas in low departure plant communities

In all cases, “departure” is a measure of similarity between the current and reference (historic) vegetation structure, with high departure reflecting vegetation heavily altered from past structural conditions, and low departure indicating a distribution of structural states that are highly similar to those we would have expected pre-European settlement. In the FVS simulations, individual stands were further prioritized for treatment according to basal area (BA) and quadratic mean diameter (QMD), so that stands with the greatest stocking (i.e., BA) and the smallest trees (i.e., QMD) would be given highest priority for treatment.

In their modeling, the investigators assumed conventional treatment scenarios and contemporary wildfire frequencies. Stands with a preponderance of large trees over 16" in diameter were not included, due to some social constraints. Carbon emissions were estimated for wildfires, prescribed burning, and pile burning. In the simulations, all thinning harvests were followed by pile burning in the second year, and by broadcast burning in the tenth year. The researchers also assumed that trees would regenerate successfully after burning.

Findings and Discussion

In their results, Vegh et al. (2013) reported that carbon emissions and stocks were affected by both management alternatives and wildfire frequency. In the reporting, carbon stocks were divided into above-ground live biomass and into total carbon occurring above- and below-ground, both live and dead. The following results were generated from the 100-year model simulation:

- The no-action alternative resulted in the lowest total carbon emissions since no treatments would occur under these alternatives. The alternatives with management treatments produced approximately five times the total carbon emissions of the no-action alternative.
- Carbon emissions by wildfire were lower in the treatment alternatives than in the no-action, and wildfire emissions were lowest in the alternative with the greatest degree of thinning. Resulting wildfire emissions associated with the heavy thinning alternative were up to half the amount of emissions of the light thinning alternative, and about one third less than the no-action alternative.
- Total carbon stocks (above- and below-ground, live and dead) were lower in the treatment alternatives than in the no-action alternative, due to thinning and the removal of live tree biomass, assuming similar wildfire frequency and severity as the last three decades (1980-2009). The lowest carbon stocks were found in the heavy thinning alternative.
- Carbon stocks for live above-ground biomass alone were highest in the treatment alternatives, particularly in the second half of the simulation due to the accumulation of carbon in large fire-resistant trees.

We might also conclude that at landscape scales, total above-ground carbon stocks would remain somewhat higher in the treatment scenarios than in the reference condition, because of the number of untreated plant communities and because of a lower overall fire frequency compared to reference (due to fire suppression activities and loss of fine fuels in some ecological systems).

Soil Organic Carbon

Soil organic carbon is the energy source for soil organisms which, through their activity and interactions with mineral matter, impart the structure to soil that affects its stability and its capacity to provide water, air, and nutrients to plant roots. The amount and kind of soil organic carbon reflects and controls soil development and, ultimately ecosystem productivity (Van Cleve and Powers, 1995).

Globally, soil organic carbon (SOC) contains more than three times as much carbon as either the atmosphere or terrestrial vegetation (Schmidt, et al, 2011). Forest soils are a critical part of any forest carbon accounting effort. Forest soils are the largest active terrestrial Carbon pool and account for 34% of the global soil carbon pool (Bucholtz, et al, 2013). Accurate quantification of regional soil C stocks is a necessary component of atmospheric CO2, soil productivity and global climate change models. Soils represent a significant portion of the active carbon cycle, with estimates of organic C on the order of 1500 to 2000 Pg C, or roughly two thirds of the terrestrial organic C stocks (Rasmussen, 2006).

Attempts to characterize regional soil Carbon stocks include both ecosystem and soil taxa based approaches. The ecosystem approach involves averaging soil C data within a specific plant community or biome and multiplying the average soil C content by the estimated biome land area (Rasmussen, 2006). This approach does not account for soil spatial heterogeneity, and results in large variability of soil C estimations within an ecosystem or biome.

The soil taxa approach has been extensively described in the soil science literature (Rasmussen, 2006) and includes segregating landscapes by soil taxa (instead of biomes) and using average taxa soil C and estimated land area to calculate soil C stocks.

The process used for the Carson NF soil C stock assessment involved the aggregation of terrestrial ecological units (soil/vegetation/climate) into ecological response units that represent the major potential natural vegetation communities on the Carson NF.

Methods

The Carson National Forest has a wide variety of soils that support many different terrestrial ecosystems. These soils have originated from igneous, sedimentary and metamorphic geologic sources and occur on a wide array of landforms of varying age. The differential weathering of soils by various climates and supporting diverse plant communities leads to the development of soil organic carbon.

Soil organic carbon was calculated from three sources for this assessment. Soil pedons that were selected for physical and chemical characterization during the Carson NF and Santa Fe NF Terrestrial Ecosystem Surveys (Edwards, et al., 1987; Miller, et al., 1993); and the Valles Caldera National Preserve Terrestrial Ecological Unit Inventory were used to establish average soil organic carbon reference values for ecological response units (ERU) that had similar life zones, vegetation and lithology. The soil pedons chosen to analyze were representative of the major kind of soil for that ERU. Other kinds of soil may also occur within ERU's however their proportion is minor relative to the representative pedon that was sampled and characterized.

Another source of soil organic carbon data came from the USDA-NRCS, National Soil Survey Office, Geospatial Research Unit at West Virginia University. The data was compiled from the Rapid Soil Carbon Assessment project initiated by the NRCS and gridded soil survey data (gSURGGO). The minimum, maximum, average and median SOC values were calculated for each ecological response unit.

Ecological Response Units were intersected with polygons from the gSURGGO data and site-specific pedon data and values for soil organic carbon were calculated for a depth of 0-100cm. These values were normalized and compared to established reference values of characterized pedons of similar soils and vegetation communities.

Bulk density was derived from both sampled pedon data and representative values from known soil textures.

Results

Soil organic carbon by ecological response unit is provided in table 5. The riparian herbaceous (RMAP Herbaceous) and Montane/Subalpine Grasslands have approximately the greatest amount of SOC per acre. Grasslands and specifically montane grasslands are known to process organic matter into organic carbon rapidly due moist climate conditions. Soils with thick, dark surface and subsurface horizon yield Mollisols which are characteristically grassland soils. The Montane/Subalpine Grasslands which are dominated by bunch grass fescues and muhly species are generally supported by very productive Haploborolls, Argiborolls and Cryoborolls.

Forested systems of the upper montane life zone such as the Mixed Conifer with Aspen ERU also produce high amounts of soil organic carbon. Largely due to the favorable climate and soils with high productivity the biomass of mixed conifer and deciduous species in this life zone is perhaps the greatest of all forested ERU's.

With respect to total area, the total tons of SOC are greatest in the Ponderosa Pine Forest primarily due to the vast acreages of this ecosystem. The Ponderosa Pine, Montane/Subalpine Grassland, Mixed Conifer-Frequent fire, Mixed Conifer with Aspen, and Spruce-Fir Forest ERU's account for 81% [>62 million tons] of the total amount of SOC for the Carson National Forest.

The lowest amount of soil organic carbon is within the RMAP ERU's consisting of the Rio Grande Cottonwood/ Shrub and Ponderosa Pine/Willow ecosystems. These riparian areas experience significant amounts of disturbances (e.g., flooding) where the above ground biomass productivity is very dynamic. Soils within the riparian areas are typically young Entisols or Inceptisols with none or little soil development. The process of accumulating and assimilating SOC in these ecosystems is very rapid. Due to the coarse soil textures and high gravel content soil organic matter passes quickly through the soil profile resulting in low SOC rates.

Table 5. Total tons and tons per acre of Soil Organic Carbon (SOC) for ecological response units of the Carson NF.

ERU	Total Tons of SOC 0-100 cm	Tons/Acre of SOC 0-100 cm
Sparsely Vegetated	99,811	13
RMAP Rio Grande Cottonwood / Shrub	29,884	10
RMAP Ponderosa Pine / Willow	3,080	10
RMAP Narrowleaf Cottonwood / Shrub	31,405	17
RMAP Narrowleaf Cottonwood-Spruce	59,089	14
RMAP Upper Montane Conifer / Willow	24,925	16
RMAP Willow - Thinleaf Alder	133,293	14
RMAP Herbaceous	3,378,144	93
Sagebrush Shrubland	641,021	11
Juniper Grass	267,113	23
PJ Sagebrush	5,097,525	23
PJ Woodland	4,501,648	25
Ponderosa Pine Forest	18,454,273	59
Montane / Subalpine Grassland	11,484,791	92
Mixed Conifer - Frequent Fire	11,240,759	61

Mixed Conifer w/ Aspen	10,888,892	83
Spruce-Fir Forest	10,401,487	36
Bristlecone Pine	77,063	17
Alpine Tundra	127,492	13
Grand Total	**76,941,693**	**631**

Comparison of results to other studies

The soil organic carbon for this analysis was compared to other studies in the southwestern USA. Rasmussen (2006) identified a range of SOC form Pinyon-Juniper (PJ) ecosystems in Arizona from 5.3-10.7 Kg/M2. The values within the Juniper Grass, PJ Sagebrush and PJ Woodland ERU's for the Carson NF soil organic carbon assessment range from 5-6 Kg/M2 (Table 6).

Within the Ponderosa Pine Forest the Carson NF values for SOC are approximately 13 Kg/m2 which are similar, although on the higher end, to previously reported values ranging from 3.4-13.5 Kg/M2 in Arizona (Rasmussen, 2006).

Meurisse et. al., (1997) reported approximately 12 and 25 tons/acre SOC for southwestern Pinyon-Juniper and Ponderosa Pine ecosystems respectively. These values are somewhat lower than those reported within this assessment. The difference is primarily due to the varying lithology supporting these ecosystems and differences in the sample load for the analysis.

Table 6. Soil Organic Carbon for Carson National Forest Ecological Response Units.

Number	ERU Code	ERU Name	SOC 0-100 cm (g/m2)	SOC 0-100 cm (kg/m2)	Acres	SOC 0-100 cm (tons)	SOC 0-100 cm (tons/acre)	SOC 0-100 cm (teragrams)
1	ALP	Alpine Tundra	2,859	3	9,996	127,492	13	0.12
2	BP	Bristlecone Pine	3,768	4	4,585	77,063	17	0.07
3	CPA	Colorado Plateau / Great Basin Grassland	5,913	6	0	0	0	0.00
4	JUGc	Juniper Grass	5,258	5	11,388	267,113	23	0.24
5	MCD	Mixed Conifer - Frequent Fire	13,781	14	182,847	11,240,759	61	10.20
6	MCW	Mixed Conifer w/ Aspen	18,639	19	130,959	10,888,892	83	9.88
7	MSG	Montane / Subalpine Grassland	20,538	21	125,351	11,484,791	92	10.42
8	PJS	PJ Sagebrush	5,258	5	217,326	5,097,525	23	4.62
9	PJOc	PJ Woodland	5,663	6	178,196	4,501,648	25	4.08
10	PPE	Ponderosa Pine -- Evergreen Oak	911	1	0	0	0	0.00
11	PPG	Ponderosa Pine Forest	13,221	13	312,900	18,454,273	59	16.74
12	190	RMAP Herbaceous	20,815	21	36,381	3,378,144	93	3.06
13	230	RMAP Narrowleaf Cottonwood / Shrub	3,872	4	1,818	31,405	17	0.03
14		RMAP Narrowleaf Cottonwood-Spruce	3,193	3	4,148	59,089	14	0.05
15	350	RMAP Ponderosa Pine / Willow	2,340	2	295	3,080	10	0.00
16	260	RMAP Rio Grande Cottonwood / Shrub	2,210	2	3,031	29,884	10	0.03
17	280	RMAP Upper Montane Conifer / Willow	3,534	4	1,581	24,925	16	0.02
18	290	RMAP Willow - Thinleaf Alder	3,193	3	9,357	133,293	14	0.12
19	SAGE	Sagebrush Shrubland	2,430	2	59,144	641,021	11	0.58
20	SGP	Shortgrass Prairie (Kiowa-Rita Blanca NGs)	13,916	14	0	0	0	0.00
21	SFM	Sparsely Vegetated	2,906	3	7,700	99,811	13	0.09
22	SFP	Spruce-Fir Forest	8,042	8	289,929	10,401,487	36	9.44

The total amount of soil organic carbon on the Carson NF is approximately 69Tg which is lower than other tree dominated Forests in other northern Regions (Farr, 2014). The SOC for global temperate forests ranges from 84-152 Tg of SOC.

Summary and Conclusions

Biomass

Table 2 summarizes reference (historic) and current carbon conditions for ERUs of the Carson NF. As one might expect, on an acre-for-acre basis ALP had the least biomass carbon concentration historically (about 1 ton/ac), while SFF has the greatest (about 94 tons/ac). The remaining ERUs ranged from 4 to 92 tons per acre, with forest ERUs have the greatest concentrations, followed by woodland, shrubland, and grassland ERUs, respectively. On a per acre basis, the 10 ERUs in Table 2 are currently in the same ranking as reference in terms of carbon storage, with the exception of MCD which has taken on considerably more biomass than reference. When also considering the relative abundance of ERUs, the ranking changes somewhat among ERUs, though SFF still has the greatest overall carbon and ALP the least, for both current and reference. Patterns of increases and decreases in carbon stocks among all ERUs are split, with four ERUs showing overall increases in current condition over reference condition, and 6 showing decreases (Table 2, Figure 1). This pattern does not hold when considering future conditions, at least for the woodland and forest systems.

In the case of future trends for forest and woodland systems, in all cases except MCD carbon stocks are projected to increase on the Carson (Figure 3). Modeling results for MCD show a slight decrease. The most substantial increases are in the woodland systems (Table 3), likely as a consequence of trends in low fire frequency and minimal forest management such as harvest thinning. Here, PJS shows an increase of over 37% above reference condition, while PJO shows an increase of about 34%. While many factors work to drive these projected increases, two primary forces are noteworthy in this process stand density and stand size (expressed in R3 modeling as stand cover class and stand size class, respectively).

Current management does not appear to be at a level of intensification adequate to keep Carson systems at biomass levels commensurate with reference conditions, particularly in the cases of fire-adapted systems and SAGE. Current conditions and management trends favor closed canopy systems which in turn store more carbon than their open canopy counterparts. In ERUs showing increases, state-and-transition modeling suggests that current management intensities are not sufficient to overcome the current overrepresentation (in relation to reference conditions) of closed states, resulting in a continuation of excess carbon storage compared to reference conditions.

Carbon Emissions

Similar to implications of biomass conditions and resource management, the research synthesis on carbon emissions convey significant trade-offs among potential carbons strategies. Although the total carbon emissions were higher for the harvest alternatives in the study considered here (Vegh et al. 2013), thinning and fuels reduction did reveal lower wildfire emissions and reduced risk of uncharacteristic wildfire. The study also suggests that, in the long term, systematic thinning and burning ultimately lead to greater live above-ground sequestration. It's also important to keep in mind that the A-S is starting with uncharacteristically high levels of biomass on the heels of a century of fire suppression, and that strategies to maximize carbon sequestration and sustain carbon stores are not necessarily compatible (Hurteau and Wiedinmyer 2010). The indirect goal of contemporary management goals is to reduce, at least in part, current carbon stocks to pre-settlement levels.

In the future, the benefits to reduced emissions and increased carbon sequestration may be more pronounced. First, because live trees continually sequester carbon and are a more stable carbon sink than dead biomass generated in particular by uncharacteristic fire, insect outbreaks, drought, and other stress, proactive management and broad-scale fuel reduction may be preferable for the long-term mitigation of atmospheric carbon. Second, there is the related issue of trees regenerating poorly or not at all following uncharacteristic fire in some forest types (Savage and Mast 2005). Others investigators (Dore et al. 2008) also show that poor regeneration after stand replacement fire in ponderosa pine can render plant communities as C sinks for many years after the fire, casting further doubt on the sustainability of a strategy that intends to maximize sequestration while indirectly promoting uncharacteristic fire and reduced ecosystem productivity (Hurteau and Wiedinmyer 2010).

The A-S study by no means represents a comprehensive analysis of the carbon emissions involved with forest management scenarios. A full accounting would include emissions involved in the harvest, transfer, and processing of any wood products, along with the sequestration and decomposition of those products and other forest residues, and the emissions involved with the associated energy consumption (Cameron et al. 2013). Cameron and others determined, on a 100-year model simulation, that even with an industrial forestry theme that the ratio of storage to emissions was 0.58. They also showed that if wood destined for paper and pulp was instead redirected to less lucrative biomass consumption that the storage ratio could increase substantially to 2.7.

Also for consideration are the effects by increased CO_2 levels on vegetation productivity and the potential for negative feedback by emissions on climate forcing. Such a feedback loop would involve carbon emitting processes, increased CO_2 levels and fertilization of the atmosphere, followed by an increase in vegetation production and increased carbon capture and sequestration (mitigation). Some research indicates that vegetation productivity does increase with elevated CO_2 levels, but productivity rates soon level off as other factors appear to compete with the growth benefits (Archer 2011, Penuelas et al. 2011).

Finally, some have forwarded the notion of *carbon carrying capacity* as a potential foundation for carbon management plans (Keith et al. 2009, 2010, Hurteau et al. 2010). Carbon carrying capacity is the maximum amount of above-ground carbon that can be sustainably stored, according to climatic conditions and the disturbance regime of a system. Carbon carrying capacity may be a useful consideration for optimizing carbon stocks according to the inherent capabilities and processes of a given ecosystem.

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Appendix 1 – Methods

Assignment of Biomass Carbon Values by Seral State – Forests and Woodlands

The Southwestern Region incorporated a process of using the Forest Vegetation Simulator (FVS) in conjunction with the Vegetation Dynamic Development Tool (VDDT) to help inform State and Transition Models (STM) that were developed in support of forest planning. One objective of this dual modeling system was to test the assumptions made by the STM developer—in some cases, this process lead to modification of some STM model parameters. Another objective of this process was to use existing forest inventory data as input into the FVS model to provide an empirical basis to more fully understand important vegetation pathways that may not have been adequately represented through expert opinion or pertinent research literature—and perhaps, therein expand the STM framework. Conversely, a development pathway conceived to be important in the STM may be shown through the FVS process to be not as prevalent as originally thought—and therefore, lead to eliminating a particular pathway in a revised STM. Finally, we know of no better way than an FVS analysis to estimate outputs for the many complex transitions that are likely to be modeled in an STM—FVS, especially when used with the Event Monitor, can be used to develop outputs such as standing and harvest volumes, fuel conditions, stand structural attributes, and biomass and carbon stocks that can be linked to vegetation states in VDDT models.

Inventory Data

The modeling process began by dividing the southwestern United States into terrestrial ecosystems that range from dry grasslands-shrublands, to semi-arid woodlands, to moist forestlands. Each ecosystem is representative of an Ecological Response Units (ERU) (a.k.a., Potential Natural Vegetation Type (PNVT)) (Schussman and Smith, E. 2006). Each ERU, which is depicted within separate VDDT models, was then further broken into vegetation states. A vegetation state is a composite of cover type (prevailing species composition) and stand structure (dominant tree size, canopy cover density, and vertical canopy layering).

During this initial phase, Forest Inventory and Analysis (FIA) plots were filtered by habitat type (USDA Forest Service 1997) to represent each ERU[2]. Table 1 provides a listing of the habitat types associated with the ponderosa pine/bunchgrass (PPG) ERU. Table 2 shows FIA plot distribution by ERU and representation by National Forest. For reference, the PPG ERU is highlighted. Table 3 lists the criteria used to develop the vegetation states for the PPG ecosystem and its associated VDDT model. Table 4 displays the FIA plot samples that were tallied for each vegetation state within the PPG ERU.

[2] The terms “habitat type” and “plant association” are synonymous in the southwestern region. An ERU is comprised of several habitat types.

Table A1. Habitat type codes associated to the ponderosa pine/bunchgrass ERU.

Habitat Type Code	Common Name
011092	ponderosa pine/Arizona fescue/blue gramma
011093	ponderosa pine/Arizona fescue/Gambel oak
011330	ponderosa pine/mountain muhly
011340	ponderosa pine/screwleaf muhly
011341	ponderosa pine/screwleaf muhly/Gambel oak
011350	ponderosa pine/Indian ricegrass
011380	ponderosa pine/black sagebrush
011390	ponderosa pine/screwleaf muhly-Arizona fescue
011391	ponderosa pine/screwleaf muhly-Arizona fescue/blue gramma
011392	ponderosa pine/screwleaf muhly-Arizona fescue/Gambel Oak
011400	ponderosa pine/kinnikinnik
011470	ponderosa pine/Arizona walnut

Table A2. Forest Inventory and Analysis (FIA) Plot Distribution by ERU.

Forest Type	ERU - VDDT Model	FIA Plots	Σ FIA Plots
Spruce-Fir_pure	Spruce-Fir Forest	21	93
Spruce-Fir_mix		72	
Mixed_Conifer-Wet	Mixed Conifer Wet (infrequent fire)	123	123
Mixed_Conifer-Dry	Mixed Conifer Dry (frequent fire)	372	372
Ponderosa-Grass	Ponderosa Pine Forest	482	788
Ponderosa-gmbOak		306	
Ponderosa-evgOak	Ponderosa Pine-Mild/Evergreen Oak	137	137
Wdlnd_PJGrass	PJ Woodland	713	1803
Wdlnd_PJOak		163	
Wdlnd_PJChap	PJ Evergreen Shrubland	303	
Wdlnd_PJSage	PJ Sagebrush	48	
Wdlnd_JUGrass	JU Grassland	268	
Wdlnd_Oak	WDL Evergreen Oak	308	
Wdlnd_None		53	970
Riparian		5	
Non-Forest		912	
Total:		4286	4286

			Plot Count			Dates	
Forest: Code	State	Name	Periodic	Annual	Total	Periodic	Annual
01	AZ	Apache-Sitgreaves	326	172	498	1996-1997	2001-2005
02	NM	Carson	235	0	235	1998-1999	
03	NM	Cibola	268	0	268	1997	
04	AZ	Coconino	301	167	468	1995-1996	2001-2005
05	AZ & NM	Coronado	282	157	439	1996-1998	2001-2005
06	NM	Gila	526	0	526	1993-1996	
07	AZ	Kaibab	247	146	393	1995-1997	2001-2005
08	NM	Lincoln	187	0	187	1997	
09	AZ	Prescott	193	107	300	1995-1996	2001-2005
10	NM	Santa Fe	255	0	255	1998-1999	
12	AZ	Tonto	464	253	717	1996-1998	2001-2005
Total:			3284	1002	4286		

Table A3. Stratification of ponderosa pine/bunchgrass ERU vegetation states A through N, according to key attributes of dominant tree size, canopy cover, and canopy layering.

	Tree Diameter					
GFB	0-5"	5-10"	10-20"	20"+	Canopy Cover[1]	Canopy Layering
A or N[2]	B	C	D	E	Open	Single
	F	G	H	I	Closed	Single
			J[3]	K[3]	Open	Multi
			L	M	Closed	Multi

[1] – Except for States A and N, "Open" states have 10 to 30% canopy cover and "Closed" states have greater than 30% canopy cover. States A and N have less than 10% canopy cover.

[2] – States A and N are grass, forbs, brush, and shrub states (GFB). State A is the characteristic state which existed in reference conditions. State N is the uncharacteristic state resulting when stand-replacing fires occur in closed canopy states. (Smith 2006)

[3] – The *desired condition* is an open multi-layered (≥ 5 age classes) state with average diameter varying by site productivity with State J occurring on low productive sites and State K occurring on high productivity sites. (Triepke et al. 2011)

Table A4. FIA sample plot counts and percentages for the PPG ecosystem.

Model	PPG	
State Class	n	%
A	32	6.6%
B	7	1.5%
C	24	5.0%
D	61	12.7%
E	18	3.7%
F	23	4.8%
G	84	17.4%
H	52	10.8%
I	6	1.2%
J	44	9.1%
K	21	4.4%
L	92	19.1%
M	18	3.7%
Total	482	100.0%

FVS Adjustments

Before projecting the FIA inventory plots with FVS, it was important to adjust default parameters for growth, mortality, and regeneration for each ERU. The purpose of performing these adjustment steps is so that the projections more closely mimic the empirical (i.e. endemic) conditions determined from the actual field measurements. One example of a situation where calibration is essential is for projecting old-forest stands. The sample base upon which the empirical growth and mortality equations in FVS are built are intrinsically not well suited to modeling old-growth forests over long time horizons, and yet typically VDDT simulations are performed for 200 to 300-year intervals. Thus, thoughtful calibration can greatly improve the realism of simulations when projecting stands over long time periods by attenuating height and diameter growth and mortality during stand senescence.

Adjustment procedures include using the FVS self-calibrating feature (for example, altering the baseline estimate of the large-tree diameter growth models), accounting for tree defect for volume estimates (adjusting net merchantable volume from gross tree dimensions), determining tree species size attainment, limiting stand maximum density, and estimating and inputting natural regeneration response (querying existing stands to tabulate their seedling component). A paper (Vandendriesche 2009a) has been written that deals with this topic in more detail, and so we will not elaborate further in this document.

Natural Growth Projections

In VDDT, the successional classes, pathways, and transition probabilities are defined for each Ecological Restoration Unit. A single ERU may have more than one set of probabilities defined to represent different management regimes or ecological conditions. In general, two types of transitions can occur. One type is movement between states due to natural succession. This process integrates background disturbances that affect regeneration, growth, and self-thinning, but not extrinsic disturbances such as insect or disease outbreaks, wildfire, or silvicultural treatment. Transitions representing natural successional dynamics (or 'natural growth') are modeled deterministically in VDDT. What this means is that transitions from one class to the next class occur when the residence time (a surrogate for successional 'age') has exceeded the value set for the state. For transitions in VDDT related to disturbances, movement between states is determined stochastically according to probabilities conveyed by modeling or set by the user.

Once the FVS adjustment procedure has been completed, we used FVS commands (keywords) to adjust growth, mortality, and regeneration responses as outlined in the above section. To model natural succession in FVS, we track residence time in a state—the average length of time that vegetation typically remains in that state before transitioning to the next state along the successional pathway. We did this by projecting all the plots in the specific ERU without invoking any disturbances such as pest effects or catastrophic wildfires in FVS. Then 250-year projections are performed for every plot, outputting tree lists and stand summaries each cycle for completing the next two steps in the process.

Classify the Tree Lists, Calculate Residence Times

In order to accomplish the integration of FVS within the VDDT-STM approach, a computer program was developed to classify inventory data into vegetation states (i.e. cover type, size class, canopy cover, canopy layers) for initial conditions and for subsequent projection cycles. The Preside program (Vandendriesche 2009b) summarizes various vegetation classes into classes and provides average time in a particular vegetation state and the probability of movement to associated states.

Preside classifies the current tree list for each plot at each projection cycle boundary. Estimates of the residence times and resultant pathways are summarized by use of an array of all possible transitions from one state to another, and indexed by vegetation state to which a plot belongs. For each plot at each cycle, its source (that is what state it began the cycle in) and destination (that is what state it ended the cycle in) are recorded. The length of time each plot remains within a state class between cycles is accumulated and the mean and variance of residence times is summarized over all the cycles and transitions in the projection. The pathways (direction of movement between source and destination) between vegetation states are also summarized using the array.

Accumulate and Summarize Outputs

At the end of an FVS projection, a set of FVS post-processing steps have been bundled together that produce aggregate summaries for each of the vegetation classes, using the sample of plots populating each vegetation state during the projection. It is then relatively easy to display graphics for communicating the STM results. For example, images from the Stand Visualization System (SVS) can be displayed for each vegetation state that is an aggregate of the plots in that state (figure 1). The post-processing programs also index the aggregate state classes to summary values derived from the tree lists, attributes from standard FVS output reports, and variables computed from the Event Monitor. This feature is useful for tracking important values such as stand volume and biomass across states (example, figure 2).

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Figure XX. Aggregate Stand Visualization System (SVS) Graphic Depictions of Vegetation States within the PPG ecosystem.

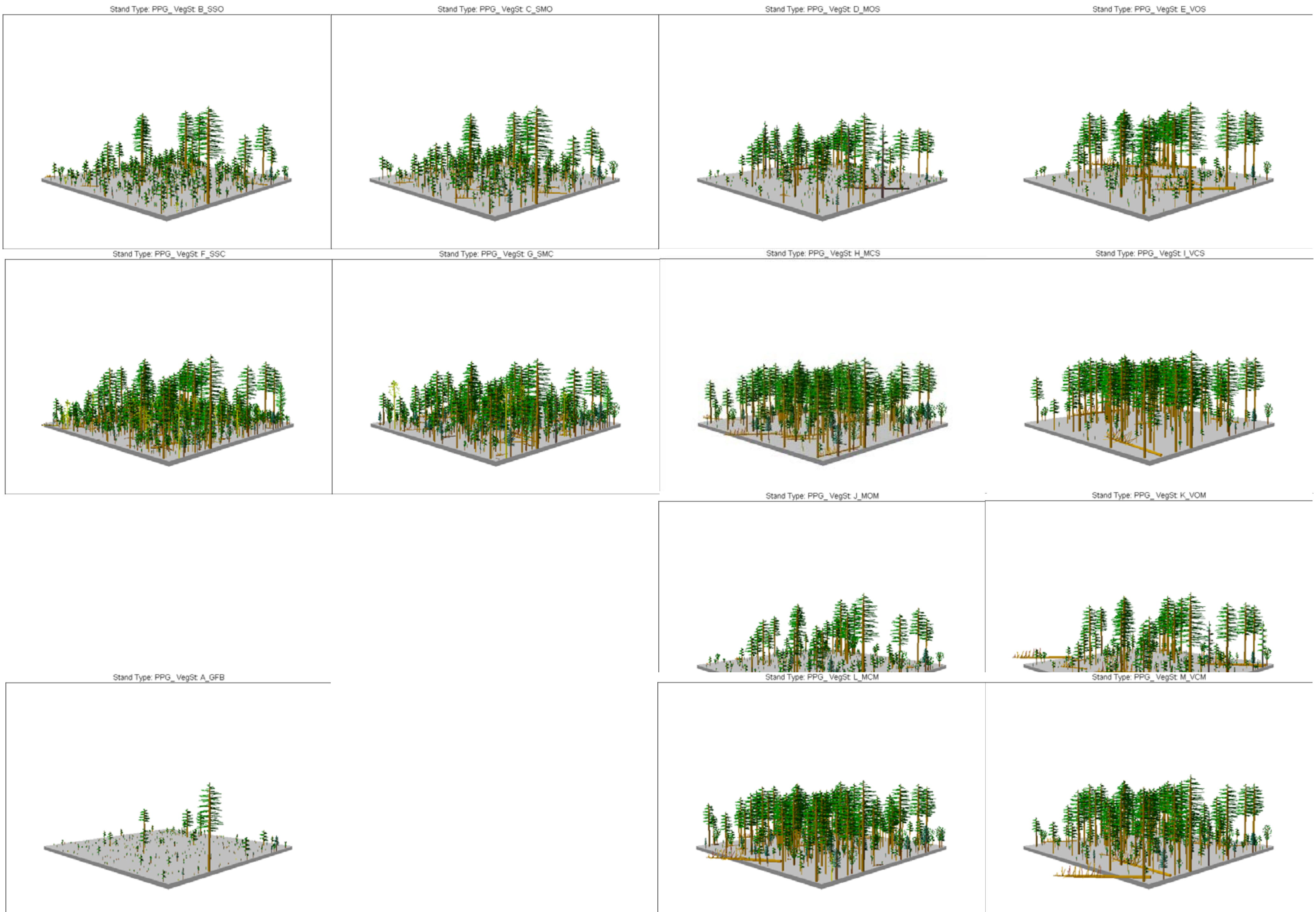

Figure XX – Aggregate Summarizes of FVS Event Monitor Computed Variables for PPG ERU.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			PPG	Ponderosa Pine - Grass ERU				Coarse-filter							
3									VDDT STATE						
4	*Computed Variables*	*Vegetation Structure Variables:*	A_GFB	B_SSO	C_SMO	D_MOS	E_VOS	F_SSC	G_SMC	H_MCS	I_VCS	J_MOM	K_VOM	L_MCM	M_VCM
5	DOM_TYPE	Dominance Type	NVG	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO	PIPO
6	CAN_SZTMB	Size Class	0	1	2	3	4	1	2	3	4	3	4	3	4
7	CAN_SZWDL	Size Class	0	1	2	3	3	1	2	3	3	3	3	3	3
8	CAN_CLASS	Canopy Class	0	1	1	1	1	2	2	2	2	1	1	2	2
9	BA_STORY	Canopy Layers	0	2	2	1	1	2	2	1	1	2	2	2	2
10	QMD_AGE	Stand Age – Overstory	11	41	74	75	93	72	99	116	139	95	114	132	150
11	CAN_AGE	Stand Age – Dominant Story	13	30	59	78	98	55	88	116	143	90	114	125	148
12	Stand_Age	Stand Age	13	30	60	80	109	55	89	118	149	91	121	128	152
13	Proj_Year St_Age/10	Stand Age/10	2	3	6	8	11	6	9	12	15	10	13	13	16
14	PLT_ACRES	Total Plot/Activity Count	46	42	74	131	150	159	893	1124	609	140	175	2847	1322
15	TRT_ACRES	Treatment Plot/Activity Count	0	0	0	0	0	0	0	0	0	0	0	0	0
16	PRP_STCK	Proportion Stockable Area	0.92	0.96	0.87	0.90	0.86	0.99	0.99	0.99	0.99	0.92	0.89	0.99	1.00
17															
18	*Stand-Stock Variables:*														
19	SEEDS/AC	Seedlings/Acre < 1.0" diameter	201	352	186	170	118	340	122	66	26	352	126	66	41
20	STEMS/AC	Trees/Acre = 1.0"+ diameter	64	280	182	114	97	892	504	264	148	184	130	315	242
21	BA_STM	Basal Area/Acre = 1.0"+ diameter	12	35	43	53	76	105	129	149	161	62	78	151	157
22	QMD_STM	Quadratic Mean Diameter – Trees = 1.0"+ diameter	6.0	4.9	6.7	9.7	14.4	4.9	7.0	10.8	15.7	8.0	10.8	9.9	11.5
23	QMD_TOP20	Quadratic Mean Diameter – Top 20 percent, diameter	0.0	8.9	10.6	15.1	21.0	8.8	11.9	16.8	24.4	15.7	19.3	17.6	21.7
24	SDI_SUM	Stand Density Index	11	71	80	89	105	213	240	243	223	102	112	247	233
25	SDI_DJ	Stand Density Index – SDI_Dj (Zeide)	33	97	129	129	165	263	274	270	256	149	171	282	272
26	SDI_DQ	Stand Density Index – SDI_Dq (Reineke)	25	76	111	113	135	216	242	245	226	119	137	248	234
27	CAN_COV	Canopy Cover Percent	6	22	23	22	22	51	51	47	40	24	24	48	44
28															
29	LCA.ALLSX	Live – Cubic Feet/Acre = 5.0"+ diameter	163	390	499	808	1969	1294	1812	2690	4215	993	1803	2811	3534
30	LBD.ALLSX	Live – Board Feet/Acre = 9.0"+ diameter	695	1659	1511	3348	11170	6102	6537	12093	23923	3952	9903	12939	19150
31	HCA.ALLSX	Harvest – Cubic Feet/Acre = 5.0"+ diameter	0	0	0	0	0	0	0	0	0	0	0	0	0
32	HBD.ALLSX	Harvest – Board Feet/Acre = 9.0"+ diameter	0	0	0	0	0	0	0	0	0	0	0	0	0
33	CUGROW	Growth - Cubic Feet/Acre/Year = 5.0"+ diameter	1.0	13.4	12.2	11.6	21.0	33.4	37.7	46.5	37.2	14.6	21.1	40.2	34.4
34	CUMORT	Mortality - Cubic Feet/Acre/Year = 5.0"+ diameter	0.2	6.0	6.0	5.0	26.9	13.9	15.6	19.6	26.5	14.0	34.9	19.4	22.5
35															
36	*Wildlife Habitat Variables:*														
37	R3_VSS	R3 – Vegetative Structural Stage	1	1	3ASS	4ASS	6BSS	2C	3CMS	4CSS	5CSS	5AMS	6BMS	4CMS	6CMS
38	SDI12%18	Percent SDI 12-18" diameter class	17	15	8	45	8	12	12	44	12	28	13	31	15
39	SDI18%24	Percent SDI 18-24" diameter class	15	11	7	15	34	11	8	22	41	16	20	19	27
40	SDI24%	Percent SDI 24"+ diameter class	10	11	10	2	45	9	9	2	37	17	44	12	32
41	*Standing Snags*														
42	SNG08T12	Small = 8-12" diameter	2	1	2	3	2	2	4	9	2	3	2	7	4
43	SNG12T18	Medium = 12-18"+ diameter	2	1	1	3	2	2	2	6	4	2	2	4	3
44	SNG18P	Large = 18"+ diameter	1	5	3	2	7	3	3	2	5	3	7	2	4
45	*Snag Recruitment (i.e. prior period mortality = 10 years)*														
46	RCR08T12	Small = 8-12" diameter	0	1	1	1	1	2	5	6	1	1	1	5	3
47	RCR12T18	Medium = 12-18"+ diameter	0	0	0	1	1	1	1	4	2	1	1	3	2
48	RCR18P	Large = 18"+ diameter	0	1	1	0	2	1	1	1	2	2	3	1	2
49															
50	*Pestilent Disturbance Variables:*														
51	DMAI	Dwarf Mistletoe Awareness Indicator (plot count)	2	6	3	11	45	32	183	248	151	22	68	527	229
52	TR_PTI	Percent Infected Host Trees = 1.0"+ diameter	3	8	4	4	27	16	15	15	21	12	39	15	15
53	SB_HZRD	Spruce Beetle Hazard	0	0	0	0	0	0	0	0	0	0	0	0	0
54	MPB_HZRD	Mountain Pine Beetle Hazard	2	2	2	2	2	2	2	3	3	2	2	3	3
55															
56	*Wildfire Risk Variables:*														
57	CRWNBLKD	Crown Bulk Density	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1
58	CRWNBSHG	Crown Base Height	11.2	6.0	10.1	13.0	24.5	9.6	9.9	18.8	28.7	15.6	19.4	15.5	19.5
59	CRWNIDX	Crowning Index	95.3	52.6	45.7	47.7	53.6	34.9	31.9	28.7	39.3	57.1	57.5	31.5	37.6
60	TRCHIDX	Torching Index	7.0	0.0	7.0	12.2	30.4	9.4	12.9	33.3	61.6	17.1	23.0	25.7	30.8
61	CWDDUFF	Fuel Load - Duff Layer	0.7	1.4	2.2	2.2	3.6	3.4	3.0	3.7	5.1	2.3	3.9	3.8	4.6
62	CWDLTTR	Fuel Load - Litter Layer	0.6	1.1	1.8	1.7	2.3	3.5	3.9	3.9	3.8	1.7	2.5	4.1	4.0
63	CWD00T03	Fuel Load – Coarse Woody Debris = 0-3" diameter	0.4	1.7	2.0	1.9	6.3	4.4	5.0	5.7	8.0	2.1	6.9	5.9	7.0
64	CWD03T12	Fuel Load – Coarse Woody Debris = 3-12" diameter	1.1	2.2	3.5	3.4	10.7	5.1	6.3	8.5	13.6	3.7	12.0	8.6	10.8
65	CWD12P	Fuel Load – Coarse Woody Debris = 12"+ diameter	0.1	1.9	3.2	0.6	8.2	1.8	3.5	3.2	7.6	2.3	10.2	4.0	6.2
66															
67	*Biomass-Carbon Variables:*														
68	TRBIOMSS	Tree Biomass – Dry weight live & dead/boles & crown	7	18	23	28	63	42	48	63	91	31	59	66	80
69	STDCARBN	Stand Carbon – Total carbon above & below ground	6	16	21	23	55	36	41	52	75	26	54	54	66

metadata / SFP / SFM / SFF / SFE / MCW / MCE / MCD / PPF / PPG / PPO / PPE / PJC / PJG / PJO / PJS / JUG / MEW_MPO