Development of Carbon Entity Guidelines for Wildfire and Prescribed Fire in the Continental United States

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Overview:

- This work was conducted for the 2022 update (Murray et al. 2023) of the USDA's 2014 report Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory.
- The objective for the 2022 update is to provide methods and guidance on estimating greenhouse gas (GHG) emissions and carbon removals associated with entity-level activities in managed forest systems across the continental U.S.
- Our contribution to the update was to estimate GHG emissions from wildfire and prescribed fire, which are limited to emissions from consumption of live and dead fuels. This was accomplished using FIA plot data in the Fire and Fuels Extension of the Forest Vegetation Simulator (FFE-FVS), using a range of fires severity settings.

Summary:

FIA data from FVS-ready tables packaged with FIADB (Shaw and Gagnon 2020) were used in FFE-FVS to establish prefire carbon pools and fuel loading for trees (live and dead), herbs and shrubs, woody fuels, litter, and duff. FFE was then used to simulate immediate fire effects—tree mortality, fuel consumption, and changes in carbon pools resulting from three wildland fire scenarios (fig. 1). GHG fire emissions were calculated as the product of fuel consumption from the FFE-FVS simulations and pollutant emission factors.

FIA data from about 70,000 plots were used to produce each of the fire severity scenarios. Because FVS is organized as a set of regional variants, subsets of FIA plots were run using the variants in which they were located. FIA plots were attributed with FIA forest type and forest type group classifications and assigned to the geographic regions used in the report framework. For the conterminous United States, over 350,000 combinations of region, forest type, and fire conditions were simulated.

To determine the mortality levels of the fire severity scenarios, FFE simulations were run using a matrix of fire-related parameters (wind speed, fuel moisture, temperature, and burn patchiness; fig. 2). The mortality resulting from a given set of parameters can vary tremendously between forest stands. Region, forest type, and stand composition and structure are critical factors in stand mortality (fig. 3), so variability among regions was not only dependent on the mix of forest types in each region, but different fire behavior in some types

across regions. Tree species and diameter are also important factors; for a given fire scenario, mortality may be highly variable across stands of the same forest type and region (fig. 4). Mortality simulation results were retained for creating estimates of GHG emissions and carbon pools.

Key Concepts for FVS Users:

- The goals of the project, as set out by the project organizers, was to achieve constrained levels of mortality that corresponded to each of the fire severity categories. The wide range of responses to similar burning conditions (i.e., FFE-FVS settings) across geographic regions due to different mixes of forest types (fig. 3), and the range of responses of single forest type among regions (fig. 4) made achieving the desired mortality levels a challenging exercise.
- Development of a matrix of FFE-FVS settings, forest types, and other attributes, with associated pre- and post-fire results is essential for data organization and analysis in projects of this scale. Further analysis is needed to test whether certain fire effects are typical of various forest types, or whether the prescribed severity levels are effectively forcing simulation developers to “push” FFE-FVS to produce results that are extreme or highly unusual for certain types in some areas.

Management Applications/Future Directions:

- Results of this analysis have been contributed to the development of a public tool, in the form of an MS Excel workbook, that allows users to enter information about their forest land. The tool then queries the data produced by this analysis and returns pre-calculated GHG emissions and carbon fluxes based on the range of severities.
- Landowners or managers need only limited expertise to obtain results from the tool, because it provides a graphical user interface (GUI) and provides limited choices for input.
- The values provided by the tool are approximate, “back of the envelope” calculations, partly owing to the relative coarseness of categories (e.g., forest type group) and limited details about stand structure, composition, etc., and partly due to the aggregation of data over large areas in the analysis, i.e., the values are averaged over a somewhat wide range of conditions.
- A planned improvement is to make the process spatially explicit by integrating TreeMap (Riley et al. 2022), which will use imputed values for various forest attributes in the actual area of interest as an input for the tool. This approach should allow for more locally-specific analysis and a more continuous range of possible outputs (as opposed to class averages). The spatially explicit approach should alleviate some of the challenges encountered when attempting to control fire severity in the simulations, and it will also allow for varying effects within the same parcel of land if there is heterogeneity of fire-related forest attributes.

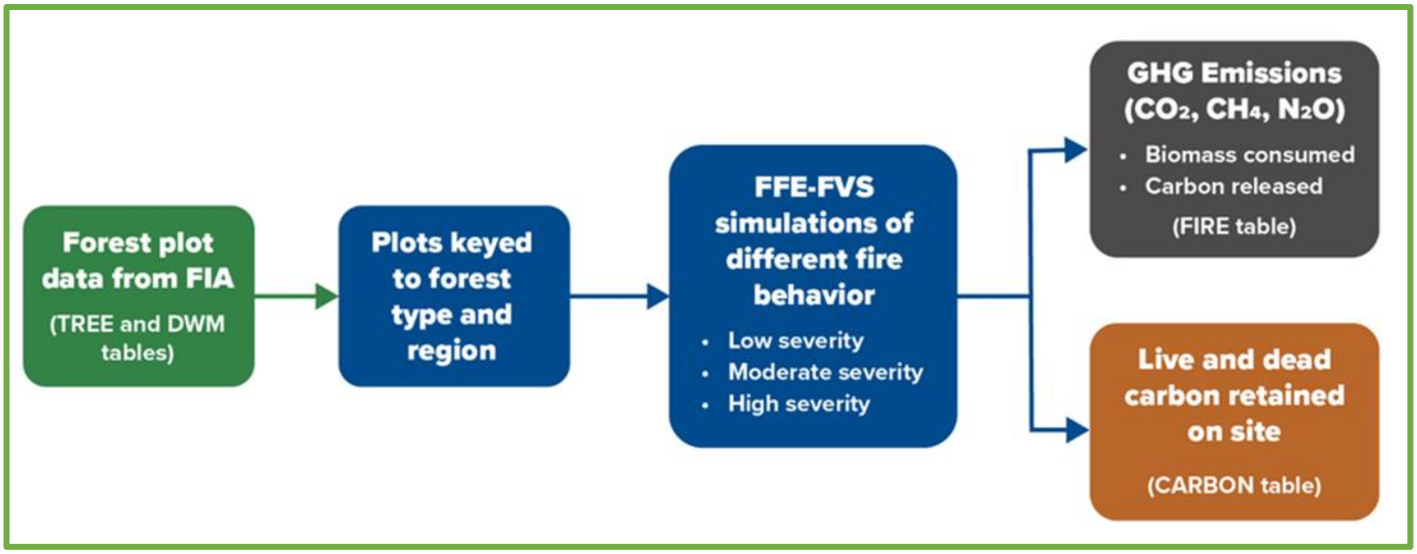

Figure 1—Analysis flow, starting with acquisition of FVS-ready FIA data through the FIA Datamart. Only plots on which downed woody material (DWM) was measured were included in the analysis.

Fire intensity	Moisture level	Wind (mph)	Temp (F)	Percent of stand burned
High	Very Dry	20	75	100
Moderate	Dry	15	70	100
Mod-Low	Moist	10	70	100
Low	Wet	5	70	90
Very low	Wet	0	65	80

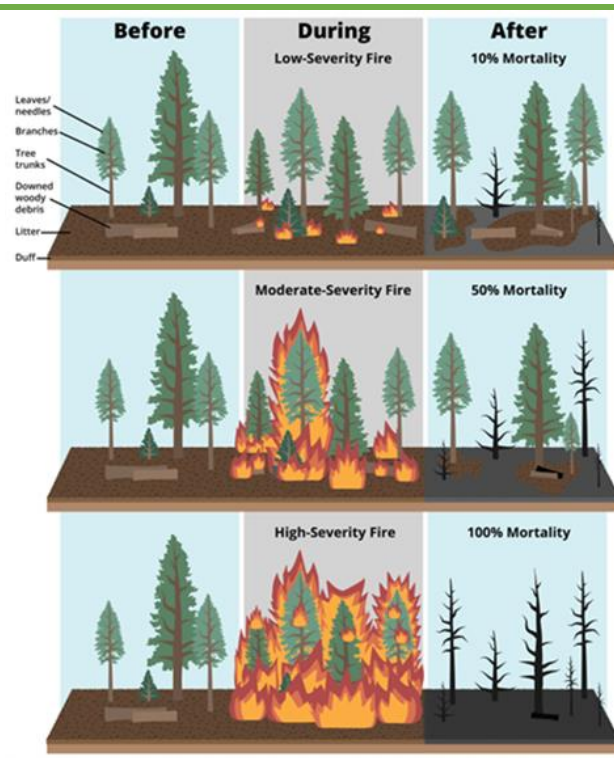

Figure 2—Target fire intensity levels and examples of FFE-FVS parameters used to achieve them. Adapted from Murray et al. 2024.

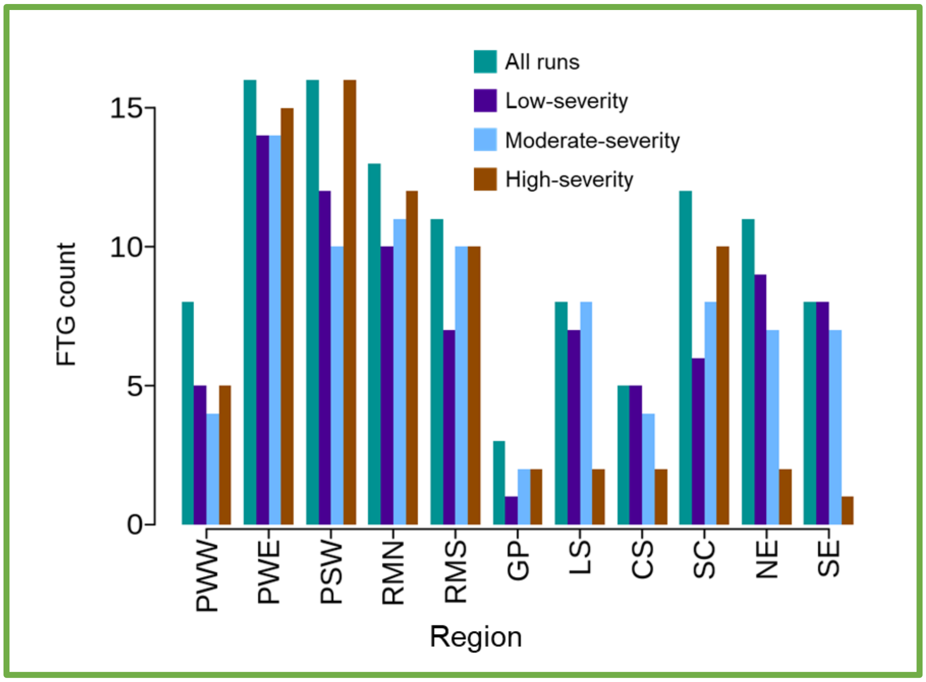

Figure 3—Although severity classes were approximately linked to mortality targets, in some cases the range of mortality targets was difficult to achieve, due to the highly variable responses among forest type groups (FTGs) to similar fire conditions. PWW: Pacific Northwest - West; PWE: Pacific Northwest - East; PSW: Pacific Southwest; RMN: Rocky Mountain - North; RMS: Rocky Mountain - South; GP: Great Plains; LS: Lake States; CS: Central States; SC: Southcentral States; NE: Northeast; SE: Southeast

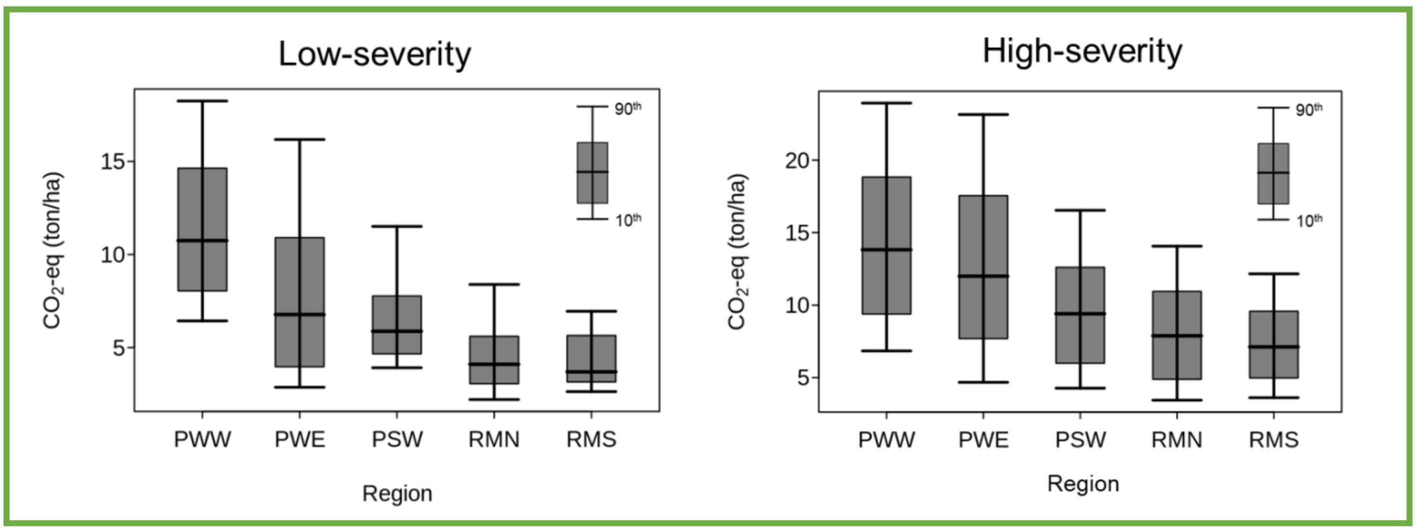

Figure 4—Variability in plot-level GHG emissions for the Douglas-fir forest type group in different subregions of the western States.

References:

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