Automating High-Resolution, Large-Extent FVS Simulations for a Carbon Accounting Protocol

David A. Schmidt[1,*], Thomas Buchholz[1], David Saah[1]

[1]Spatial Informatics Group, *dschmidt@sig-gis.com

Overview:

- SIG's REM (Reduced Emissions from Megafires) carbon accounting protocol was designed to help provide upfront funding for fuel reduction projects and was approved through the Climate Forward program of the Climate Action Reserve in March 2023.
- REM projects critically depend on several FVS simulations to quantify the effects of proposed fuels treatments on forest growth and yield, carbon stocks, fire behavior, and smoke emissions over the course of a 40-year simulation period.
- We developed a semi-automated and replicable process using TreeMap tree inventory data to facilitate the integration of large-extent (project-scale up to the scale of multi-state regions), high-resolution (as fine as 30-m stands) FVS modeling outputs into Monte Carlo fire behavior simulations with SIG's GridFire model and emissions estimates using FOFEM.

Summary:

Manually setting up, executing, and post-processing FVS simulations can be a time-consuming and tedious process. Furthermore, stand polygons appropriate for use in FVS simulations are not universally available, nor is relatively current ready-to-use tree inventory data with which to parameterize those stands. We solved these problems by utilizing the FIA-based TreeMap dataset (Riley et al. 2021) in an innovative collection of scripts that can be executed on-demand through an in-house microservice computing infrastructure.

The REM protocol (Climate Forward 2023) stipulates evaluating a proposed project in terms of its cumulative GHG emissions over a 40-year period that begins when fuels treatments are fully implemented. This involves two sets of FVS simulations: one in which the project treatments are not simulated, and another in which they are (fig. 1). Each set consists of nine individual full-length FVS simulations: a no-wildfire simulation plus eight wildfire simulations (one for each timestep). These wildfire simulations differ in the timing of a simulated wildfire burning under severe weather conditions that affects all stands. Fuels data from these 18 simulations are then fed into SIG's GridFire spatial wildfire behavior simulation software to quantify the indirect effects of the proposed fuels treatments, as well as into the FOFEM model, which is used to quantify several species of wildfire-related emissions (fig. 2).

The FVS modeling required by the REM protocol would be impractical to complete manually, even when using the FVSOnline interface on a high-performance server. We developed a

method to streamline these simulations and distribute the computational workload over distributed servers.

Key Concepts for FVS Users:

- We developed scripts that process GIS data, set up FVS simulations, execute them using the fvsOL R package, process the outputs for use in the other models, and finally query the outputs to produce the summaries of carbon stocks, fire behavior, smoke emissions, and other outputs required by the REM protocol.
- FVS stands are programmatically created as unique combinations of TreeMap stand ID, past disturbances, and proposed treatments. This allows us to handle individual stands as small as 900 square meters while growing stand conditions forward to the current year and simulating past wildfires, fuel treatments, and timber harvests that may have occurred after the current TreeMap release. Individual phases of this process are handled by separate microservers that idle on distributed Linux servers until receiving a request.
- The primary inputs for the entire process are a vector spatial data file which defines the spatial distribution of the proposed fuels treatments and a collection of FVS addfiles that define the specific keywords needed to simulate those treatments. Project proponents are required to provide an Esri shapefile that defines the location and timing of each proposed treatment type. This shapefile provides a link to a collection of addfiles, built by SIG to define the specifications of these treatments, into the FVS simulations to quantify the effects of the treatments.
- This process allows SIG to efficiently construct and execute complex FVS simulations involving tens or hundreds of thousands of stands that would otherwise be computationally infeasible.

Management Applications/Future Directions:

- Although FVSOnline provides a powerful interface to FVS, the fvsOL R package lends itself well to scripted workflows, particularly when many large-extent simulations are required.
- TreeMap's imputed tree inventory dataset is not currently released annually and is typically unable to match the accuracy of local field inventory data; nevertheless, it is an invaluable resource that enables high-resolution FVS simulations on any forested land, regardless of jurisdiction. TreeMap's stand attributes can be grown forward to current conditions when FVS is provided with an adequate spatial record of past forest disturbances.
- Although FFE–FVS only simulates stand-level fire behavior modeling, it can provide the stand-level fuels data (e.g., canopy cover and canopy base height) required for spatial fire behavior modeling. These tabular FVS outputs can provide the attributes for spatial stand information via database queries. Non-forest fuels data can be filled in with LANDFIRE or other sources.
- We are working on improving two key aspects of our approach: the assignment by FFE-FVS of fire behavior fuel models to stands and the simulation of natural forest regeneration in variants that do not include a full establishment model. Currently, we

review the assigned pre- and post-treatment fuel models and intervene only when post-treatment fuel models produce fire behavior that is inconsistent with field experience or the literature. Similarly, stands simulated with no background tree regeneration over a 40–year period are sometimes skewed with respect to metrics like canopy base height that affect simulated fire behavior. We are investigating the use of FIA sapling inventory data to improve these results.

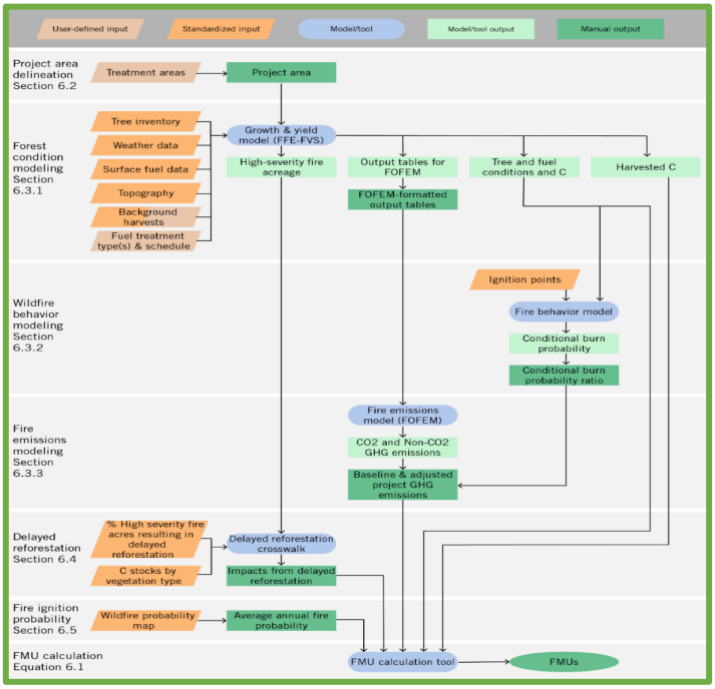

Figure 1—Overview of the role of FVS in the REM protocol.

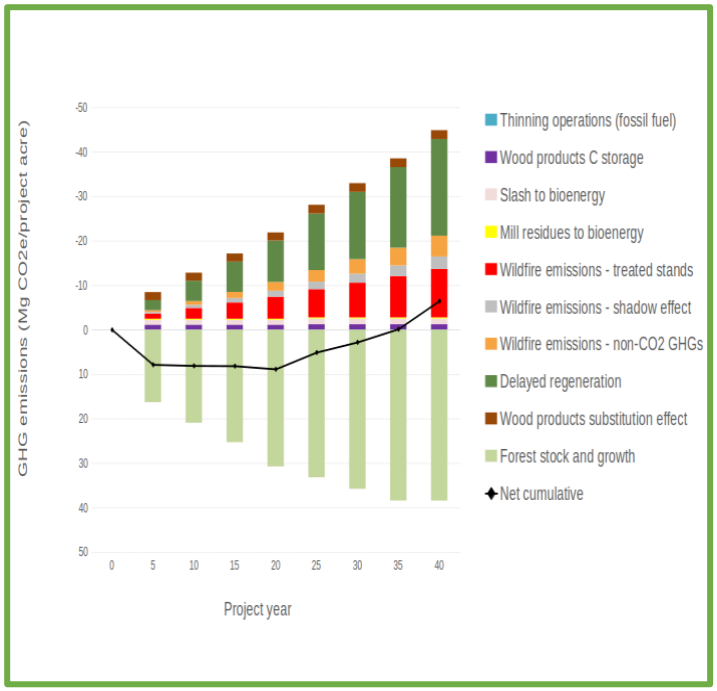

Figure 2—Example of REM components.

References:

Climate Forward. 2023. Reduced emissions from megafires (REM) forecast methodology. https://climateforward.org/program/methodologies/reduced-emissions-from-megafires/ [Accessed 28 October 2024]

Riley, K.L.; Grenfell, I.C.; Finney, M.A.; [et al.] 2021. TreeMap, a tree-level model of conterminous US forests circa 2014 produced by imputation of FIA plot data. Sci Data 8: 11. https://doi.org/10.1038/s41597-020-00782-x