USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Mapping Carbon: Forest Inventory and Analysis, TreeMap, and the Forest Vegetation Simulator

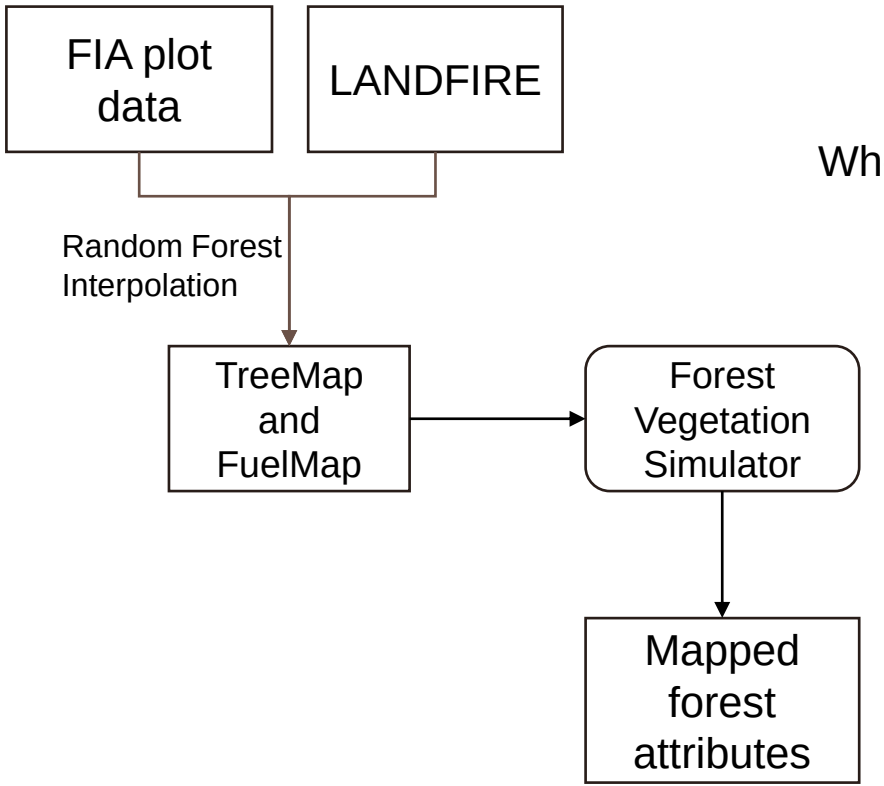
Rachel M. Houtman, Karin Riley, John Shaw (USDA Forest Service)

Rachel M. Houtman

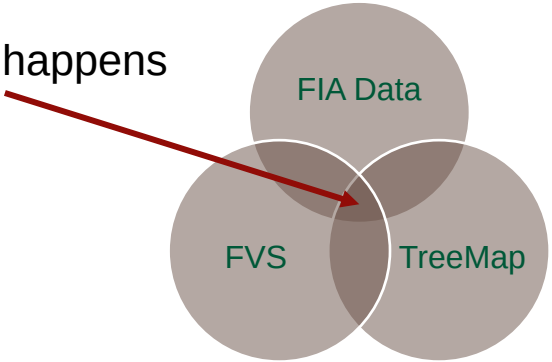
Biological Scientist, USDA Forest Service, Missoula Fire Sciences Lab

4/10/2024 Growth Model Users Group Conference

Stand data + Spatial data layer + Stand growth model



Where the magic happens



Forest Inventory and Analysis

FIA is a nation-wide assessment of forest lands that consists of multiple parts.

1 plot per 6,000 acres (approx.).

Remeasured every 5-10 years.

These are direct-measured forest plots across land ownerships (plot locations are not available to the public).

The FIA program maintains a database of all plots that are available to the public.

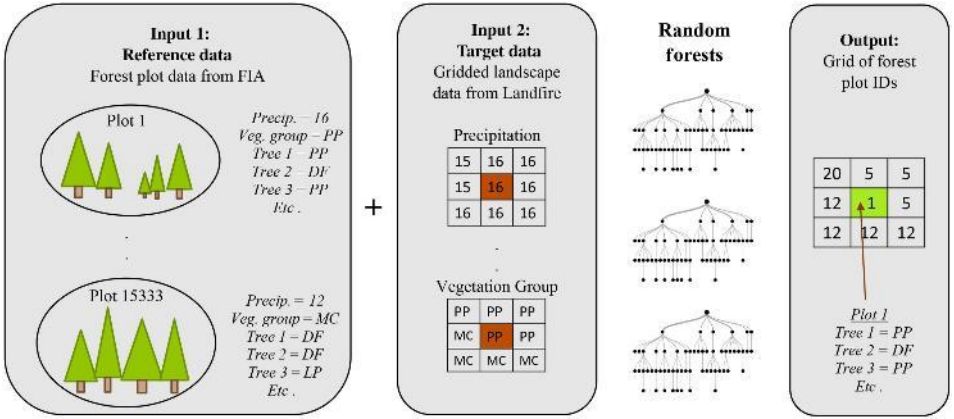
Fuels are measured on a subset of plots.

TreeMap

CONUS-wide dataset of FIA plot data interpolated to gridded LANDFIRE data.

Current versions available were created using 2014 and 2016 LANDFIRE, 2020 and 2022 versions are in process.

Datasets are available from the Research Data Archive and 2016 TreeMap is now available on Google Earth Engine.



FuelMap

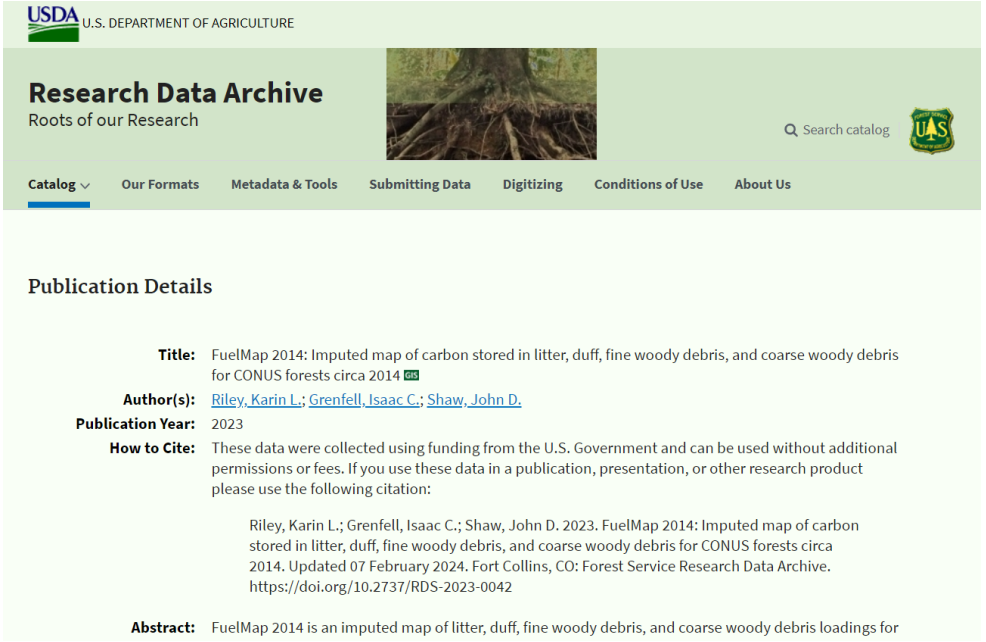
Fuels include litter, duff, fine woody debris, and coarse woody debris.

Fuels influence

- Carbon
- Fire behavior
- Habitat

Fuel transects in FIA are collected only for a subset of plots.

FuelMap allows for direct loading of these fuel values into the FVS database, rather than the default values.



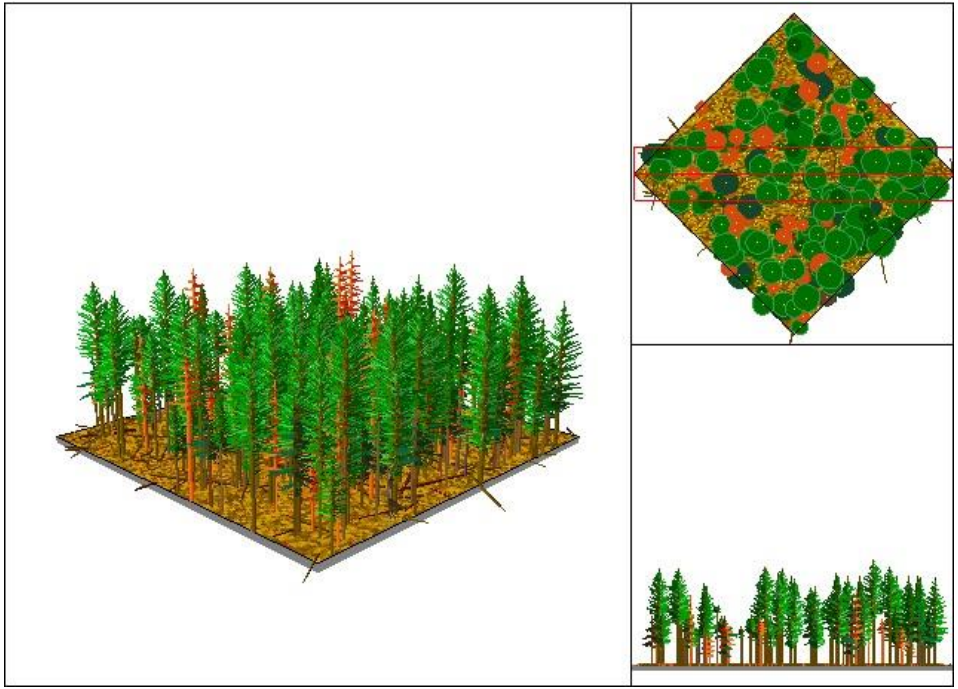
The Forest Vegetation Simulator

A Forest Service-maintained stand-based forest growth model

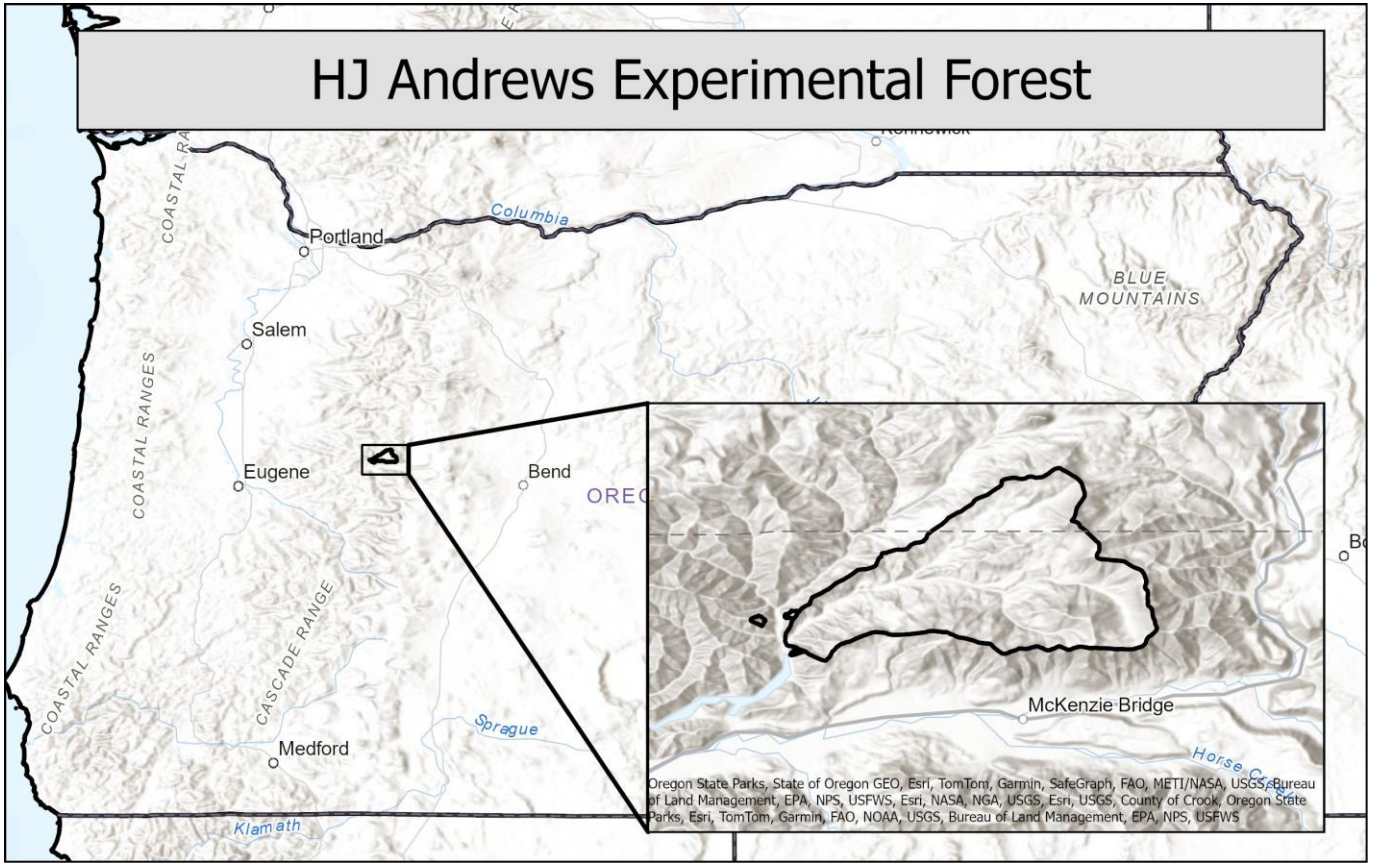
Multiple geographic variants for CONUS and Alaska.

The model can compute and report a wealth of stand-level characteristics, including volume, fire behavior, carbon, and more, as well as individual tree attributes like post-fire mortality.

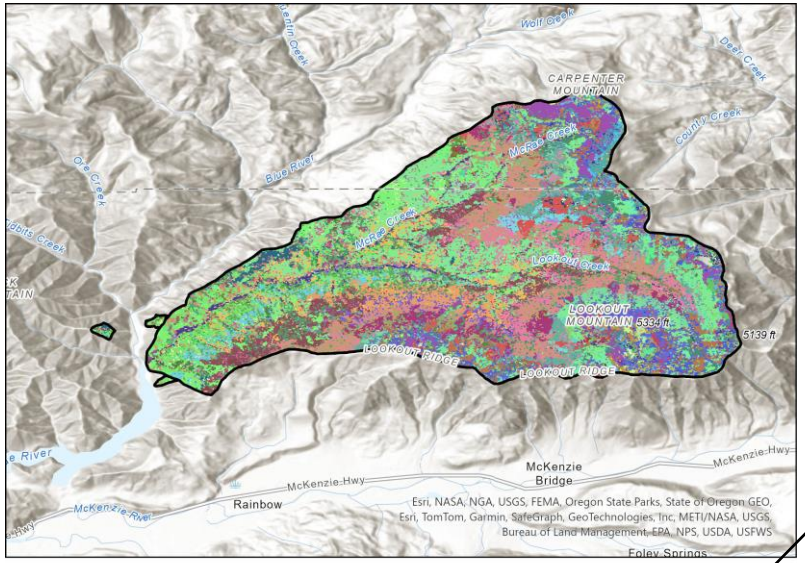
Requirements include a stand table with a tree list for every stand, length of simulation (in years), and desired outputs.

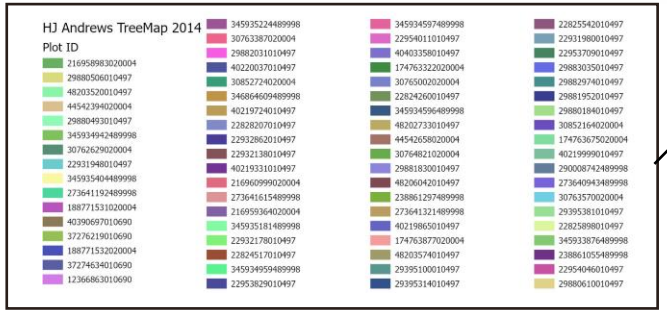


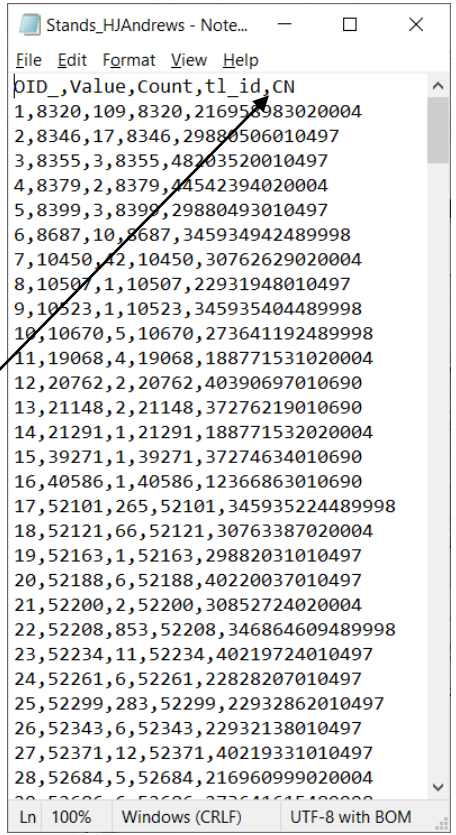
Example Application on the HJ Andrews Research Forest



Identify TreeMap plots within the study area boundary







FVS Stand and Tree List Tables

Stand List Table (FVS_StandInit)

	STAND_CN	STAND_ID	VARIANT	INV_DAY	INV_YEAR	INV_MONTH
1	12366863010690	00302007020501089929 05	IE	8	2014	8
2	13208906010497	00412005050601043897 25	WC	23	2014	9
3	1747631070200 04	00412013020301043985 59	WC	28	2014	7
4	1747631320200 04	00412013020301043754 20	WC	26	2014	7
5	1747631480200 04	00412013020301039570 98	WC	18	2014	6
6	1747631590200 04	00412013020301039759 41	WC	14	2014	6
7	1747632510200 04	00412013020301043911 55	WC	25	2014	7
8	1747633140200 04	00532013020307041737 87	WC	31	2014	7
9	1747633220200 04	00412013020302019709 30	WC	14	2014	6
10	1747633820200 04	00412013020301043734 00	WC	28	2014	7
11	1747634170200 04	00412013020301039657 92	WC	15	2014	8
12	1747635560200 04	00412013020300047840 86	WC	3	2014	8
13	1747635590200 04	00412013020301043716 26	WC	15	2014	6
14	1747635860200 04	00412013020300047758 59	WC	18	2014	7
15	1747636190200 04	00412013020301039747 56	WC	15	2014	7
16	1747636260200 04	00412013020300047837 51	WC	22	2014	7
17	1747636340200 04	00412013020301039733 24	WC	9	2014	7
18	1747636360200 04	00412013020301039700 47	WC	2	2014	7

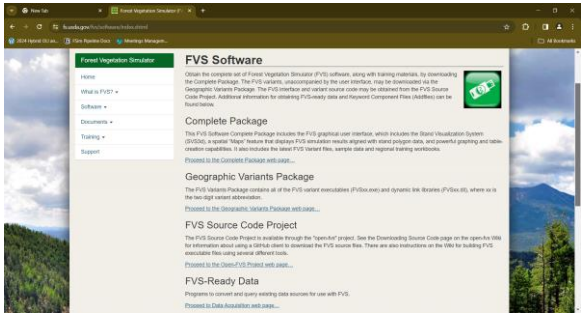
Tree List Table (FVS_TreeInit)

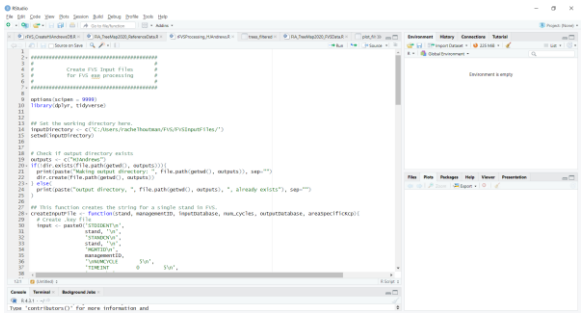
	STAND_CN	STAND_ID	PLOT_CN	STANDPLOT_CN	STANDPLOT_ID	PLOT_ID	TREE_CN	TREE_ID	TAG_ID	AZ
1	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366875010690	1	NA	
2	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366876010690	2	NA	
3	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366877010690	3	NA	
4	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366878010690	4	NA	
5	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366879010690	5	NA	
6	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366880010690	6	NA	
7	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	12366881010690	7	NA	
8	12366863010690	00302007020501089929 05	12366863010690	12366863010690_3	00302007020501089929 05_3	3	12366882010690	1	NA	
9	12366863010690	00302007020501089929 05	12366863010690	12366863010690_3	00302007020501089929 05_3	3	12366883010690	2	NA	
10	12366863010690	00302007020501089929 05	12366863010690	12366863010690_3	00302007020501089929 05_3	3	12366884010690	3	NA	
11	12366863010690	00302007020501089929 05	12366863010690	12366863010690_3	00302007020501089929 05_3	3	12366885010690	4	NA	
12	12366863010690	00302007020501089929 05	12366863010690	12366863010690_3	00302007020501089929 05_3	3	12366886010690	5	NA	
13	12366863010690	00302007020501089929 05	12366863010690	12366863010690_4	00302007020501089929 05_4	4	12366887010690	1	NA	
14	12366863010690	00302007020501089929 05	12366863010690	12366863010690_1	00302007020501089929 05_1	1	S12366890010690	1002021	NA	
15	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	S12366891010690	1000172	NA	
16	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	S12366892010690	1002022	NA	
17	12366863010690	00302007020501089929 05	12366863010690	12366863010690_2	00302007020501089929 05_2	2	S12366893010690	1002422	NA	

FVS Inputs → Run FVS → FVS Outputs → Extract Outputs with rFVS2GIS → FVS Outputs Key Table → Join Key Table to GIS raster

Running FVS

- Two options for running FVS:
  - FVS Online
    - Forest Service User Interface that runs FVS online.
    - Great for users who have minimal experience with FVS.
  - rFVS (there are now multiple “rFVS” programs out there – this is mine)
    - Simple R script that creates FVS input files to run FVS directly from executable files on a local machine.
    - Requires working knowledge of both R and FVS.





FVS Inputs → Run FVS → FVS Outputs → Extract Outputs with rFVS2GIS → FVS Outputs Key Table → Join Key Table to GIS raster

FVS Simulation Outputs

Some FVS outputs include:

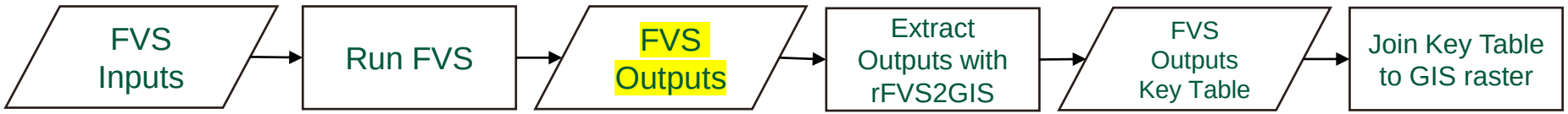
- General stand characteristics: Forest type, basal area, tree volumes.
- Carbon: total carbon and by pool, total carbon emitted and by pool.
- Fire behavior: potential, fuel consumption by pool.

****** CARBON REPORT VERSION 1.0 ******
STAND CARBON REPORT (BASED ON STOCKABLE AREA)
ALL VARIABLES ARE REPORTED IN TONS/ACRE

STAND ID: 216958983020004 MGMT ID: 2169

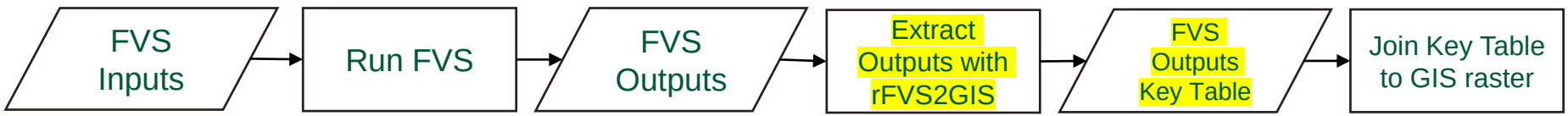
	Aboveground Live		Belowground			Forest			Total	Total	Carbon
YEAR	Total	Merch	Live	Dead	Stand Dead	DDW	Floor	Shb/Hrb	Stand Carbon	Removed Carbon	Released from Fire
2020	24.5	13.5	7.4	1.3	5.2	13.6	5.7	0.2	57.8	0.0	0.0
2021	24.8	13.7	7.5	1.3	5.1	13.3	5.2	0.2	57.5	0.0	0.0
2022	25.0	13.8	7.6	1.2	5.1	13.2	5.0	0.2	57.3	0.0	0.0

Example FVS carbon report from .out file. FVS output data are compiled for each stand in a SQLite database table for easy processing.

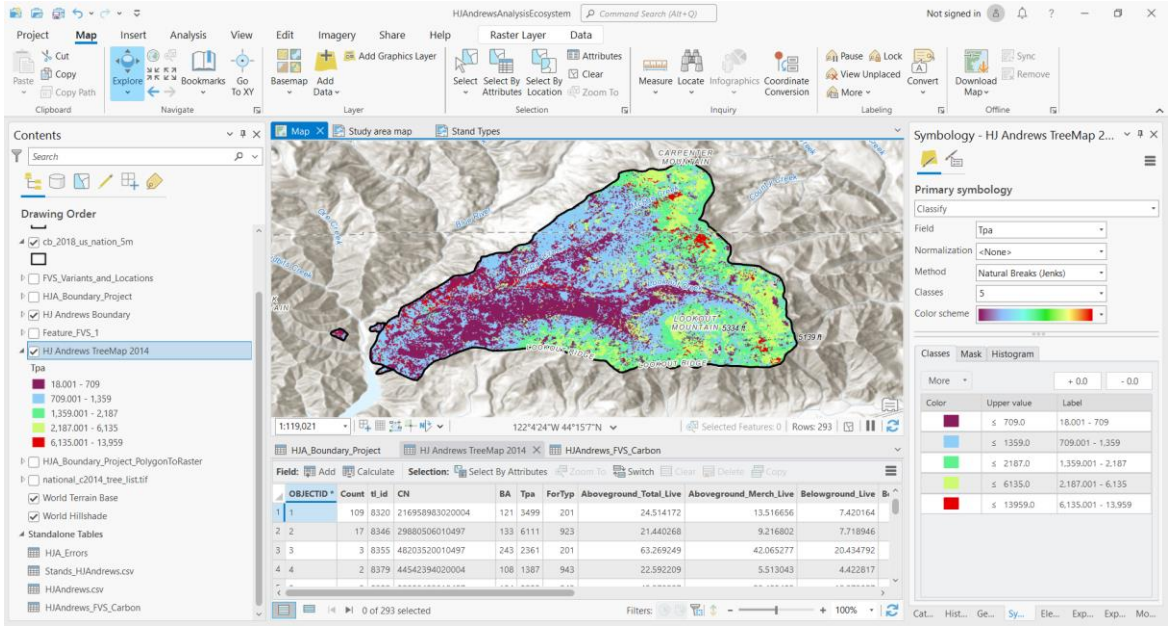


Connecting FVS back to GIS data

- rFVS2GIS code extracts all the data fields desired from the FVS dataset.
- Key value connects FVS outputs to GIS data. This may be the Stand ID, or some combination of Stand ID, FVS variant, and other landscape characteristics such as treatment locations.

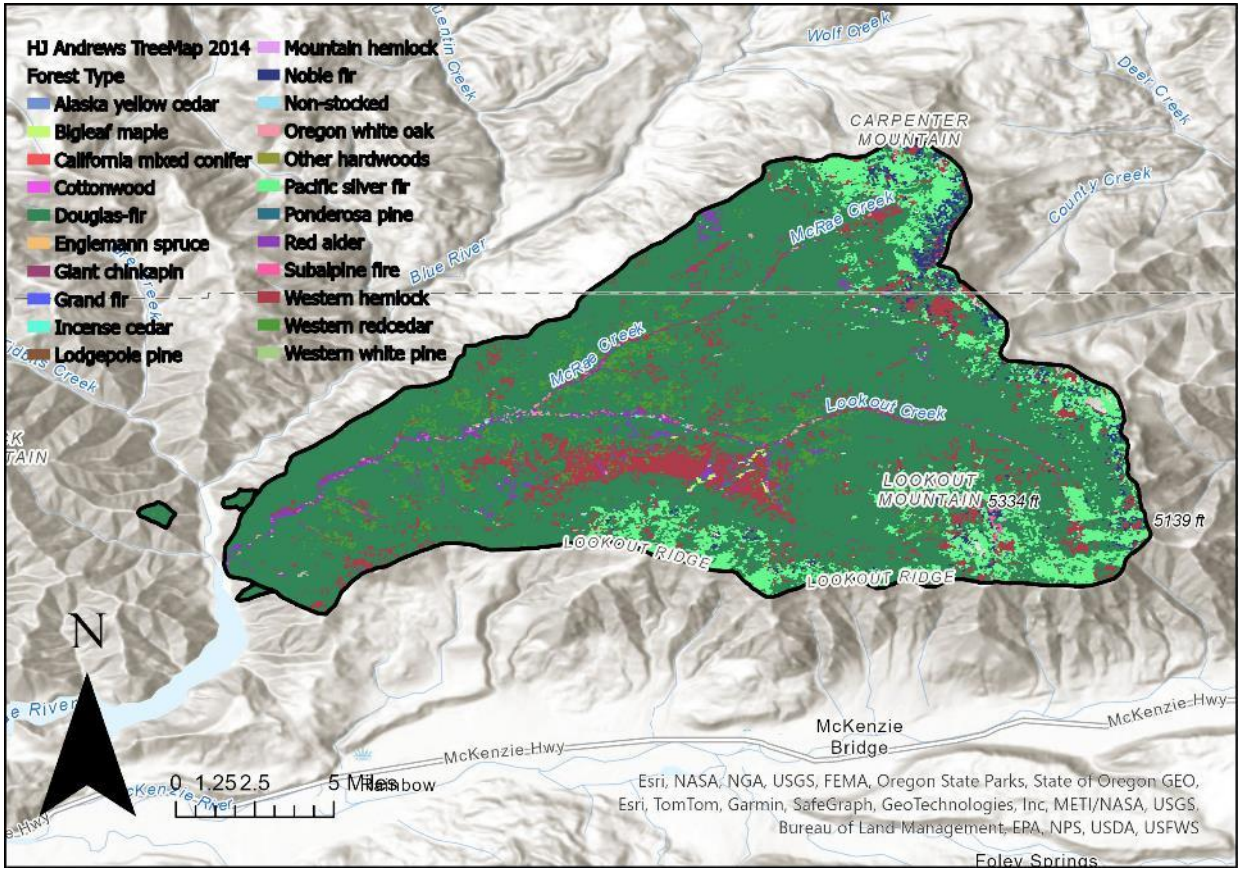


Mapping forest attributes

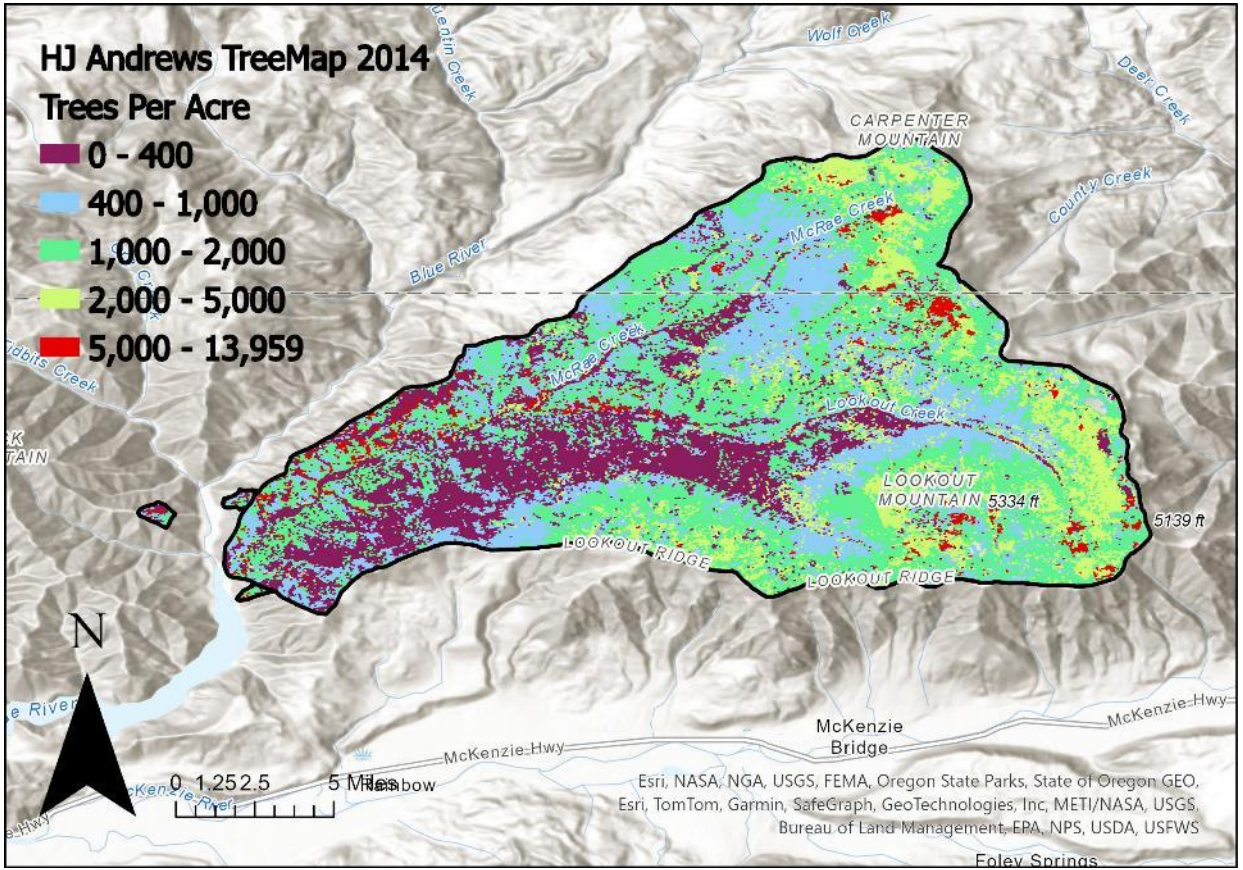


FVS Inputs → Run FVS → FVS Outputs → Extract Outputs with rFVS2GIS → FVS Outputs Key Table → Join Key Table to GIS raster

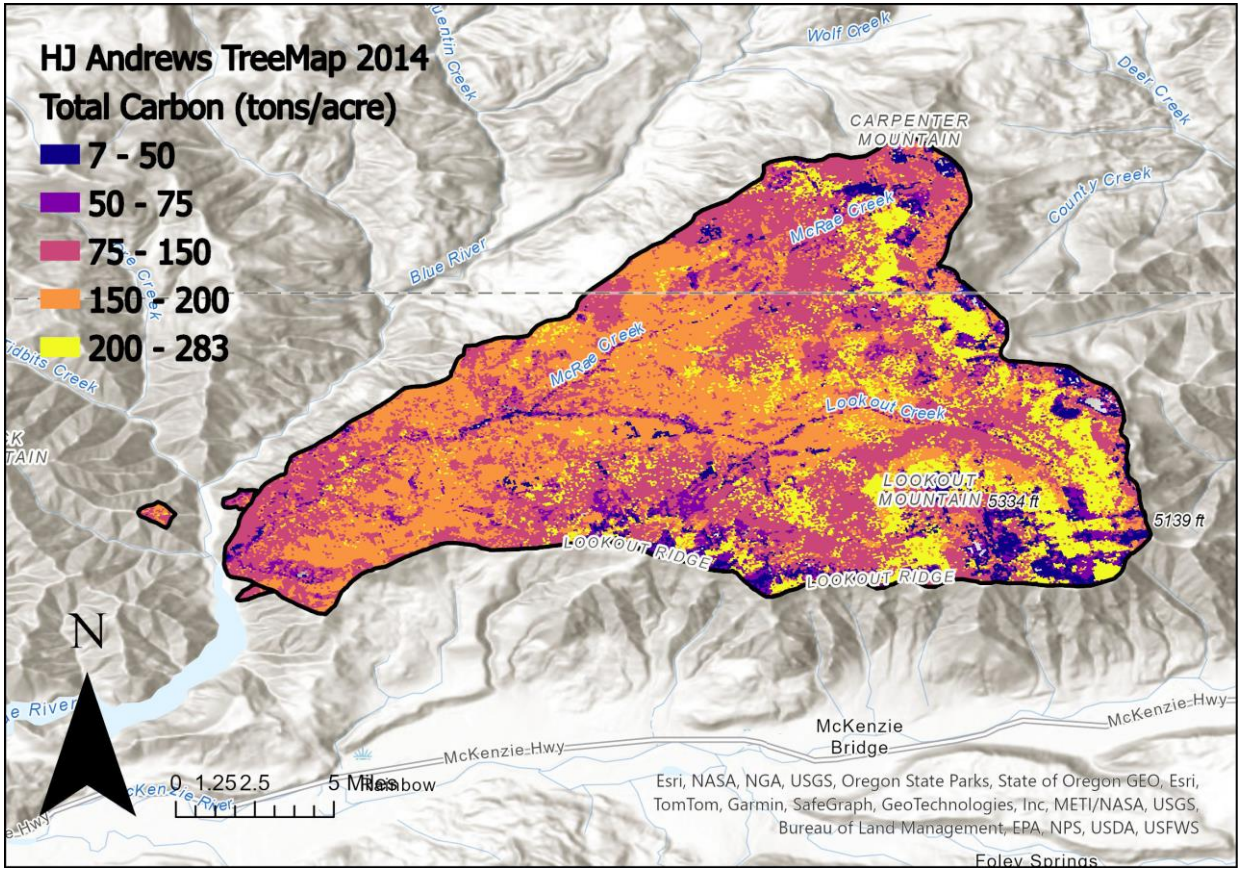
Forest type


HJ Andrews TreeMap 2014
Forest Type
Alaska yellow cedar
Bigleaf maple
California mixed conifer
Cottonwood
Douglas-fir
Engelmann spruce
Giant chinkapin
Grand fir
Incense cedar
Lodgepole pine
Mountain hemlock
Noble fir
Non-stocked
Oregon white oak
Other hardwoods
Pacific silver fir
Ponderosa pine
Red alder
Subalpine fire
Western hemlock
Western redcedar
Western white pine
Wolf Creek
Deer Creek
CARPENTER MOUNTAIN
County Creek
McRae Creek
Blue River
McRae Creek
Lookout Creek
LOOKOUT MOUNTAIN 5334 ft
5139 ft
LOOKOUT RIDGE
LOOKOUT RIDGE
N
0 1.252.5 5 Miles
McKenzie Hwy
McKenzie Bridge
McKenzie Hwy
Esri, NASA, NGA, USGS, FEMA, Oregon State Parks, State of Oregon GEO, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS
Foley Springs

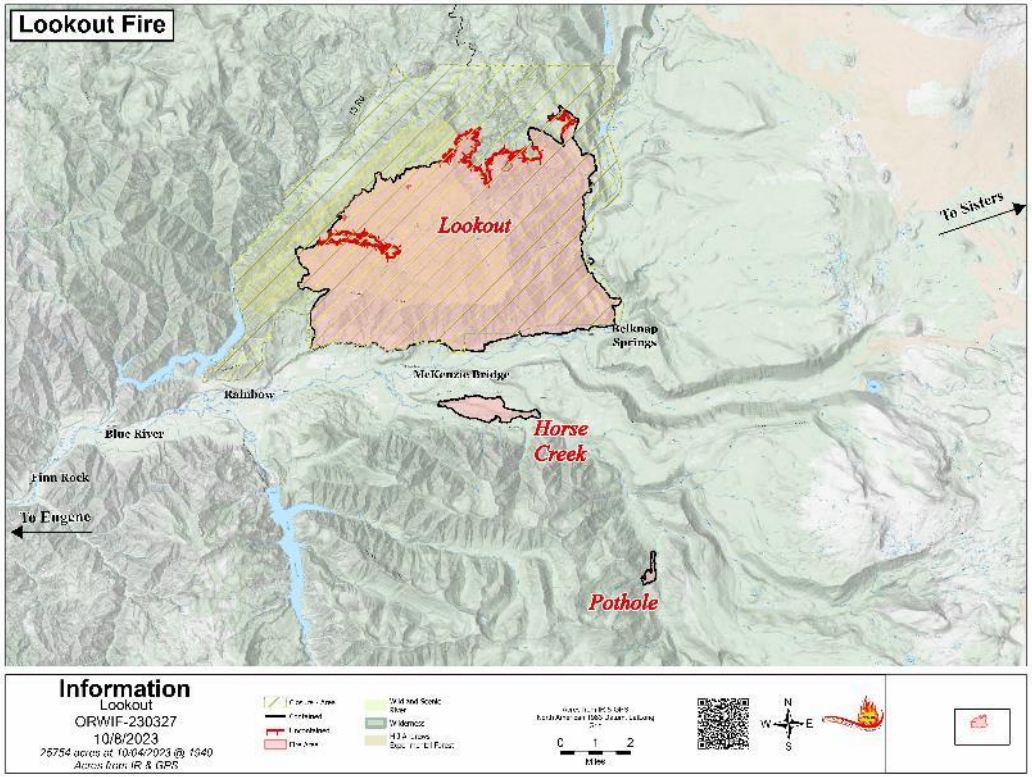
Trees per acre mapped



Total carbon mapped



Context for the area: The 2023 Lookout Fire



Questions?

How I decompress after a day of modeling

Citations

Citations

Dixon, Gary E. comp. 2002 (Revised: August 10, 2023). Essential FVS: A user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 226p.

Rebain, Stephanie A. comp. 2010 (Revised: February 1, 2022). The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 409p.

Riley, Karin L., Grenfell, Isaac C., Finney, Mark A., Wiener, Jason M. 2021. TreeMap, a tree-level model of conterminous US forests circa 2014 produced by imputation of FIA plot data. Scientific Data. 8: 11.

Riley, Karin L., Grenfell, Isaac C., Shaw, John D. 2023. FuelMap 2014: Imputed map of carbon stored in litter, duff, fine woody debris, and coarse woody debris for CONUS forests circa 2014. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2023-0042

Scott JH, Short KC, Finney MA. 2018. FSim: the large-fire simulator guide to best practices. Available online: https://pyrologix.com/wp-content/uploads/2019/11/FSimBestPractices_0.3.1.pdf Accessed: 1/10/2024.

FVS and carbon/emissions

- Run each stand through FVS with fires at each flame length to estimate carbon emissions under each flame length.
- Extract FVS outputs, including (but not limited to):
  - Total initial carbon
  - Total carbon emitted
  - Carbon emitted by pool
  - Total carbon remaining on site
- Join these attributes back to our mapped stands for analysis

****** CARBON REPORT VERSION 1.0 ******
STAND CARBON REPORT (BASED ON STOCKABLE AREA)
ALL VARIABLES ARE REPORTED IN TONS/ACRE

STAND ID: 15148182010497 MGMT ID: 1514

	Aboveground Live		Belowground			Forest			Total	Total	Carbon
YEAR	Total	Merch	Live	Dead	Stand Dead	DDW	Floor	Shb/Hrb	Stand Carbon	Removed Carbon	Released from Fire
2010	4.3	1.9	1.5	0.0	0.0	1.1	0.0	0.4	7.2	0.0	0.0
2011	1.8	0.9	0.6	0.9	2.5	0.4	0.1	0.4	6.6	0.0	1.3
2012	1.9	1.0	0.6	0.9	2.3	0.5	0.1	0.4	6.8	0.0	0.0

****** FIRE MODEL VERSION 1.0 ******
FUEL CONSUMPTION & PHYSICAL EFFECTS REPORT (BASED ON STOCKABLE AREA)
STAND ID: 15148182010497 MGMT ID: 1514

	PERCENT MINERAL SOIL	FUEL CONSUMED (TONS/ACRE)											% TREES	SMOKE PRODUCTION (TONS/ACRE)	
YEAR	EXPOSR	LITR	DUFF	0-3"	3"+	3-6"	6-12"	12"+	HERB& SHRUB	CRWNS	TOTAL CONS.	%CONSUME DUFF	3"+	WITH CRWNG	<2.5	< 10
2011	39	0.6	0.0	0.6	0.7	0.4	0.2	0.0	0.5	0.5	2.8	51	57	0	0.02	0.02

FVS carbon pool and fuel consumption outputs for a single stand