Regionally Adapted Models for the Rapid Assessment of Vegetation Condition After Wildfire Program in the Interior Northwest and Southwest United States

Craig Baker, Brian Harvey, Saba Saberi, Alicia Reiner, and Max Wahlberg[1]

ABSTRACT.—The Rapid Assessment of Vegetation Condition After Wildfire program (RAVG) provides satellite-based estimates of basal area loss, canopy cover loss, and burn severity following large wildfires on USDA Forest Service lands. The current RAVG models (regression equations) are based on field data collected from burned areas in the Sierra Nevada, northern California, and southern Oregon, and on Landsat imagery from the same period. In collaboration with teams from the University of Washington and the Forest Service Enterprise Team, the Forest Service Geospatial Technology and Applications Center is pursuing a multiyear effort to develop new models adapted to forests in the Pacific Northwest and the Southwest. The UW team is developing the model for the Northwest using data collected on wildfires in interior Oregon and Washington, northern Idaho, and western Montana that occurred during 2016 and 2017. The Enterprise Team is pursuing a similar effort for Arizona and New Mexico based on data from fires that burned in 2017 and 2018. This talk will provide background for the RAVG program and existing models, methods used in the current studies, and preliminary results.

The Rapid Assessment of Vegetation Condition After Wildfire (RAVG) program is a postfire vegetation assessment program conducted by the Forest Service Geospatial Technology and Applications Center. Its purpose is to provide model-based estimates of vegetation condition (burn severity) following large wildfires on forested lands in support of the Forest Service silviculture community.

RAVG models consist of regression equations relating imagery-based burn severity indices—most often the Relative Differenced Normalized Burn Ratio (RdNBR) (Miller and Thode 2007)—to field-based measures: burn severity basal area (BA) mortality, canopy cover (CC) mortality, and the composite burn index (CBI). The models were developed by Forest Service staff in the Pacific Southwest region based on field data collected on fires in the Sierra Nevada, northern California and southern Oregon, and contemporary Landsat imagery (Miller et al. 2009). Although the models are based on data from the specific region just described, they have been applied routinely to forested ecosystems throughout the conterminous United States.

The purpose of this new effort is to generate models tailored to other areas, based on data from those regions, with the goal of incorporating the new models into the RAVG workflow for the respective areas. The regions addressed in this project are the interior northwestern United States ("Northwest"), including eastern Oregon and Washington, northern Idaho, western Montana and northwestern Wyoming, and the southwestern United States ("Southwest"), comprising Arizona and New Mexico. The work is being accomplished through partnerships with the University of Washington's School of Environmental and Forest Sciences (for the Northwest model) and the Forest Service Enterprise Program (the Southwest model).

[1] Remote Sensing Specialist (CB), USDA Forest Service, Geospatial Technology and Applications Center, 125 South State Street, Suite 7105, Salt Lake City, UT 84138; Assistant Professor (BH), University of Washington, School of Environmental and Forest Sciences; Research Scientist (SS), University of Washington, School of Environmental and Forest Sciences; Fire Ecologist (AR), USDA Forest Service, Enterprise Program, Amherst, MA; and Fire Ecologist (MW), USDA Forest Service, Enterprise Program, Portland, OR. CB is corresponding author: to contact, email at craig.baker@usda.gov.

The project has three major components:

- Collect field data from burned areas (fires) and nearby unburned areas.
- Calculate burn-related indices from contemporary moderate resolution multispectral imagery.
- Develop models relating the field data to the imagery-derived indices.

Data were collected during the field season of the year following each fire. Fires and plot locations were selected to include forests and woodlands representative of the respective region and to sample the full range of burn severity conditions. The focus was on Forest Service lands, although the Northwest dataset includes two fires on National Park Service lands (Yellowstone and Grand Teton National Parks) with vegetation similar to that found on National Forests in the region. Each field crew sought to sample approximately the same number of plots in each of four categories of burn severity: unburned, low severity (light surface fire), moderate severity (severe surface fire), and high severity (crown fire). Fires that included each severity class were preferentially selected in the Southwest, while fires lacking forest vegetation types were not sampled. In order to increase sampling efficiency and sample size, only fires with reasonable road access were included. Field protocols established minimum distances from roads (100 m) and between plots (400 m). A fraction of the "unburned" plots was located near but outside of the selected fires in areas with vegetation and topographic characteristics similar to those of the burned area plots.

For each circular, 30-m diameter plot, field crews recorded CBI, a sample of canopy cover and individual tree data, and, in the Northwest plots, surface char. The CBI was calculated as a composite score of fire severity ratings by strata (substrate, understory, herb/low shrub, tall shrub, intermediate, and overstory tree) using standardized criteria (Key and Benson 2005). Canopy cover was measured along the north-south and east-west diameter using a densiometer. The Northwest crew took 8 samples on each plot (4 along each transect); the Southwest crew took 17 samples (9 along the North-South transect and 8 along the East-West transect). Species, diameter at breast height, and live/dead state were noted for all trees within the plot. For dead trees, crews noted whether the trees were alive or dead before the fire (e.g., identifying trees killed by insects prior to the fire). In the Northwest, additional data, including tree height and fire effects data (e.g., char height), were collected on the five tallest trees in each quadrant. In the Southwest, similar data were collected on the first five trees encountered working clockwise in each quadrant in order to allow the Forest Vegetation Simulator (FVS) (Dixon 2002) to calibrate allometric equations used in canopy cover and BA calculation.

Field crews in each region collected data from more than 300 plots over the course of two field seasons (see Fig. 1 and Table 1). In the Northwest, data were collected from 84 plots during the summer of 2017 on five fires from 2016 and from 228 plots during the summer of 2018 on nine fires from 2017. Lodgepole pine was the dominant tree species on plots at higher elevations, with subalpine fir as a lesser component. On lower-elevation plots, ponderosa pine and Douglas-fir were dominant; some grand fir were also present. In the Southwest, field crews collected data during the late spring and early summer of 2018 and 2019, with 218 plots on 15 fires from 2017 and 142 plots on 6 fires from 2018. Ponderosa pine was the dominant species across almost all elevations sampled in the Southwest. Several juniper and oak species (generally alligator and Rocky Mountain juniper, and Emory, Gambel and Arizona white oak) were a large component in some southern and lower-elevation areas. The northernmost and highest elevation plots had a mix of Douglas-fir, white fir, subalpine fir, aspen, and limber pine.

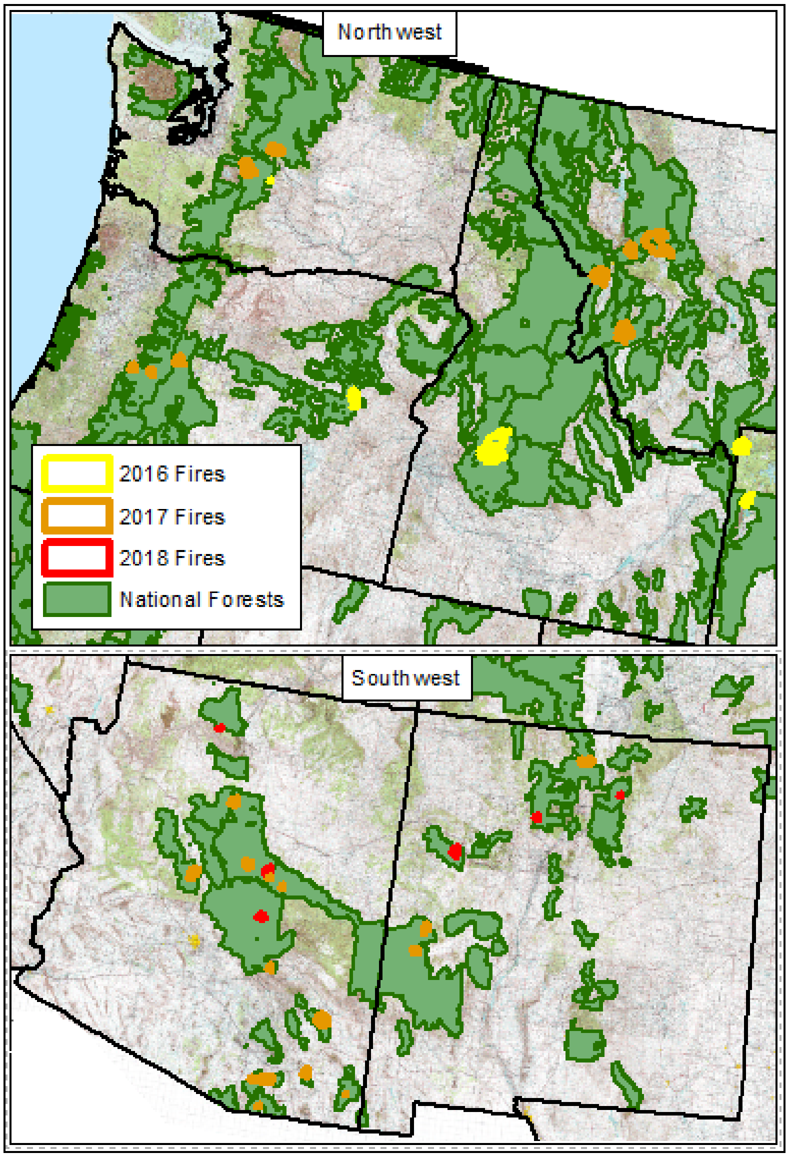

Figure 1.—Locations of sampled fires.

Stand metrics were generated from field data. Prefire BA was estimated from the subset of trees that were alive before the fire. In the Northwest, prefire canopy cover was estimated from regression models built on BA and canopy cover measured on unburned plots and applied to live prefire BA for all plots. In the Southwest, FVS was used to generate estimates of canopy cover from tree species and live BA FVS-generated canopy cover estimates were calibrated by way of adjustment factors available within FVS, which were selected to yield the best match between field-measured and FVS-generated canopy cover. Additional canopy cover data will be assembled using established photo interpretation methods with high resolution pre- and postfire imagery for improved assessment of canopy cover change for the Southwest models.

Burn severity indices were derived from Landsat 8 multispectral satellite imagery. The RdNBR is the primary burn severity index used in the RAVG program. For this project, two other burn severity indices (the differenced NBR (dNBR) and the relative burn ratio (RBR) will also be tested. Consistent with the current RAVG workflow, the indices are calculated from a pair of satellite images—one each pre- and postfire—that are judiciously selected by an analyst so as to reveal fire-related changes and minimize changes due to other factors such as annual or seasonal differences or non-fire disturbances.

Table 1.—Fires sampled and number of plots

Fire year (ignition)	Fire	National Forest (NF) or Park (NP)	State	Plots sampled
		Northwest		
2016	Berry	Grand Teton NP	WY	27
2016	Maple	Yellowstone NP	WY	10
2016	Pioneer	Boise NF	ID	13
2016	Rail	Wallowa-Whitman NF, Malheur NF	OR	23
2016	Rock Creek	Okanogan-Wenatchee NF	WA	11
2017	Jolly Mountain	Okanogan-Wenatchee NF	WA	12
2017	Jones	Willamette NF	OR	27
2017	Liberty	Lolo NF	MT	9
2017	Lolo Peak	Lolo NF	MT	21
2017	Meyers	Beaverhead-Deerlodge NF	MT	24
2017	Milli	Deschutes NF	OR	65
2017	Norse Peak	Okanogan-Wenatchee NF	WA	35
2017	Rebel	Willamette NF	OR	8
2017	Rice Ridge	Lolo NF	MT	27
		Southwest		
2017	33 Springs	Apache-Sitgreaves NF	AZ	14
2017	Baca	Gila NF	NM	24
2017	Bonita	Carson NF	NM	29
2017	Boundary	Coconino NF, Kaibab NF	AZ	14
2017	Flying	Coronado NF	AZ	15
2017	Frye	Coronado NF	AZ	21
2017	Goodwin	Prescott NF	AZ	13
2017	Hondito	Carson NF	NM	7
2017	Kerr	Gila NF	NM	14
2017	Lizard	Coronado NF	AZ	10
2017	Pinal	Tonto NF	AZ	10
2017	Rucker	Coronado NF	AZ	9
2017	Sawmill	Coronado NF	AZ	7
2017	Slim	Apache-Sitgreaves NF	AZ	10
2017	Snake Ridge	Coconino NF	AZ	21
2018	Bears	Tonto NF	AZ	17
2018	Blue Water	Cibola NF	NM	26
2018	Deiner Canyon	Cibola NF	NM	30
2018	Sardinas Canyon	Carson NF	NM	21
2018	Tinder	Coconino NF	AZ	26
2018	Venado	Santa Fe NF	NM	22

Analysis is underway in each region to determine models that best predict percent BA loss, percent CC loss, and CBI as a function of the imagery-derived indices. A variety of model forms will be assessed. In the Northwest, model development is well underway. Additional burn-related metrics are being evaluated to suggest methods to capture burn severity more accurately than with CBI methods. In the Southwest, exploratory analysis is being conducted to increase awareness of data distribution and collinearity among variables, as well as outliers and leverage points. Test error and other model accuracy metrics will be generated within cross-validation procedures (such as k-fold) and used to compare the utility of candidate models. The model with the best test error and accuracy metrics will be formulated using the entire dataset. Thresholds defining low, medium and high CBI categories will be also be identified.

Additional work being considered includes incorporation of other predictor variables (e.g., topographic indices or vegetation type), which also entails determining variable importance rankings (i.e., using Random Forests algorithms). The use of other satellite sensors (i.e., Sentinel-2) and other approaches to scene selection (e.g., seasonal composites) are also options. Follow-on work may include accuracy assessments of new and existing models as well as assessment of the need for additional models tailored to other regions of the United States.

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