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Photoload calibration of fine woody fuels in montane forests of Colorado: 2016-2017

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Introduction

Forest restoration treatments implemented to improve forest health, reduce wildfire hazard, and move forests towards desired conditions are occurring at large scales throughout montane and dry conifer forests (Caggiano, 2017; Cannon et al., 2018; Dickinson and SHSFRR, 2014; Schoennagel et al., 2009; Schultz et al., 2012; USDA Forest Service, 2018). The Colorado Forest Restoration Institute (CFRI) monitors implementation and ecological effects of fuel reduction and ecological restoration treatments across forested lands in Colorado. Surface fuels are an important driver of fire behavior and accurate estimates of fine woody fuel loading are vital to understanding the arrangement of fuels and predicting potential fire behavior (Hiers et al., 2009; Keane and Dickinson, 2007; Tinkham et al., 2016). Fine woody fuels, defined as dead wood on the forest floor less than 3 inches (7.6 cm) in diameter, are divided into time lag size classes based on the fuel moisture response time to changes in ambient moisture, including 1-hour (< 0.25 in diameter; < 0.6 cm), 10-hour (0.25–1 in diameter; 0.6–2.5 cm), and 100-hour (1–3 in diameter; 2.5–7.6 cm) fuels. A technique called photoload sampling has recently emerged that allows rapid estimation of surface fuels. With this technique, users compare surface fuels to reference photographs of known fuel loading to visually estimate surface fuel loads (Keane and Dickinson, 2007). However, fuel loading estimates from this technique tend to overestimate low surface fuel loading and underestimate high surface fuel loading. Estimation biases can be reduced by a double sampling technique, where visually estimated fuel loadings are calibrated using direct measurements using a regression approach (Tinkham et al., 2016). To improve predictions of surface fuel loadings following restoration and fire mitigation treatments in montane forests of the Colorado Front Range, we developed calibration equations for 1-, 10-, and 100-hour fuels from more than 100 plots in 12 fuel reduction and restoration projects.

Methods

We collected photoload calibration samples at twelve hazardous fuel reduction projects across montane forests in Colorado, concentrated mostly in the Front Range. Fuel reduction activities included mechanical thinning, hand thinning, clearcutting, and mastication. We collected woody fuels in stands before fuel reduction treatments, and in some cases, up to 3 years following treatments. We collected fuels in a range of forest types including ponderosa pine, ponderosa pine with a gambel oak understory, mixed conifer, and lodgepole pine (Table 1).

Table 1: Forest type, treatment, and number of plots for photoload calibration in each stand.

Site	Forest type	Treatment	Number of plots
Boy Scout Ranch	ponderosa pine	pre-treatment	7
Boy Scout Ranch	ponderosa pine	thin	6
Douglas County	ponderosa pine & gambel oak	mastication	2
Fox Run	ponderosa pine	thin	13
Long Scraggy	mixed conifer	pre-treatment	8
Nighthawk	mixed conifer	pre-treatment	4
Osprey	mixed conifer	pre-treatment	3
Payne Gulch	ponderosa pine	pre-treatment	19
Red Feather RX	mixed conifer	pre-treatment	12
Ridge Road	mixed conifer	pre-treatment	6
Ridge Road	mixed conifer	thin	4
Ramsey-Shockey	ponderosa pine	pre-treatment	2
Ramsey-Shockey	ponderosa pine	thin	11
Summit County	lodgepole pine	clear cut	6
Top of the Pines	ponderosa pine	thin	10

Table 2: Fine woody fuel linear regression results by size class.

Size Class	Regression Equation (tons/acre)	sample size	R-squared	RMSE
1-hr	Biomass = 0.05 + 0.49*Photoload	113	0.51	0.18
10-hr	Biomass = 0.22 + 1.15*Photoload	112	0.49	0.49
100-hr	Biomass = 0.05 + 1.45*Photoload	105	0.80	0.44

We conducted fuels treatment effectiveness monitoring between 2016 and 2017, using standard protocols to gather information on forest overstory composition and structure, surface fuel loading, and understory plant composition (CFRI 2017). We visually estimated fine woody fuel loading for each size class in 1 m^2 quadrats using the photoload sampling technique (Keane and Dickinson, 2007). We collected woody fuels from one quadrat per plot and separated fuels according to size class (1-, 10-, and 100- hour fuels). We oven dried all samples at 50°C for at least 3 days before recording dry weights of each sample to the nearest 0.01 g and converting weights to tons ac^{-1} to match units used in photoload estimates.

We generated separate linear regression calibration models for each woody fuel size class using field photoload estimates to predict the corresponding observed biomass. As future monitoring sample sizes increase, a more robust exploration of the impact of surveyor and use of mastication may be warranted.

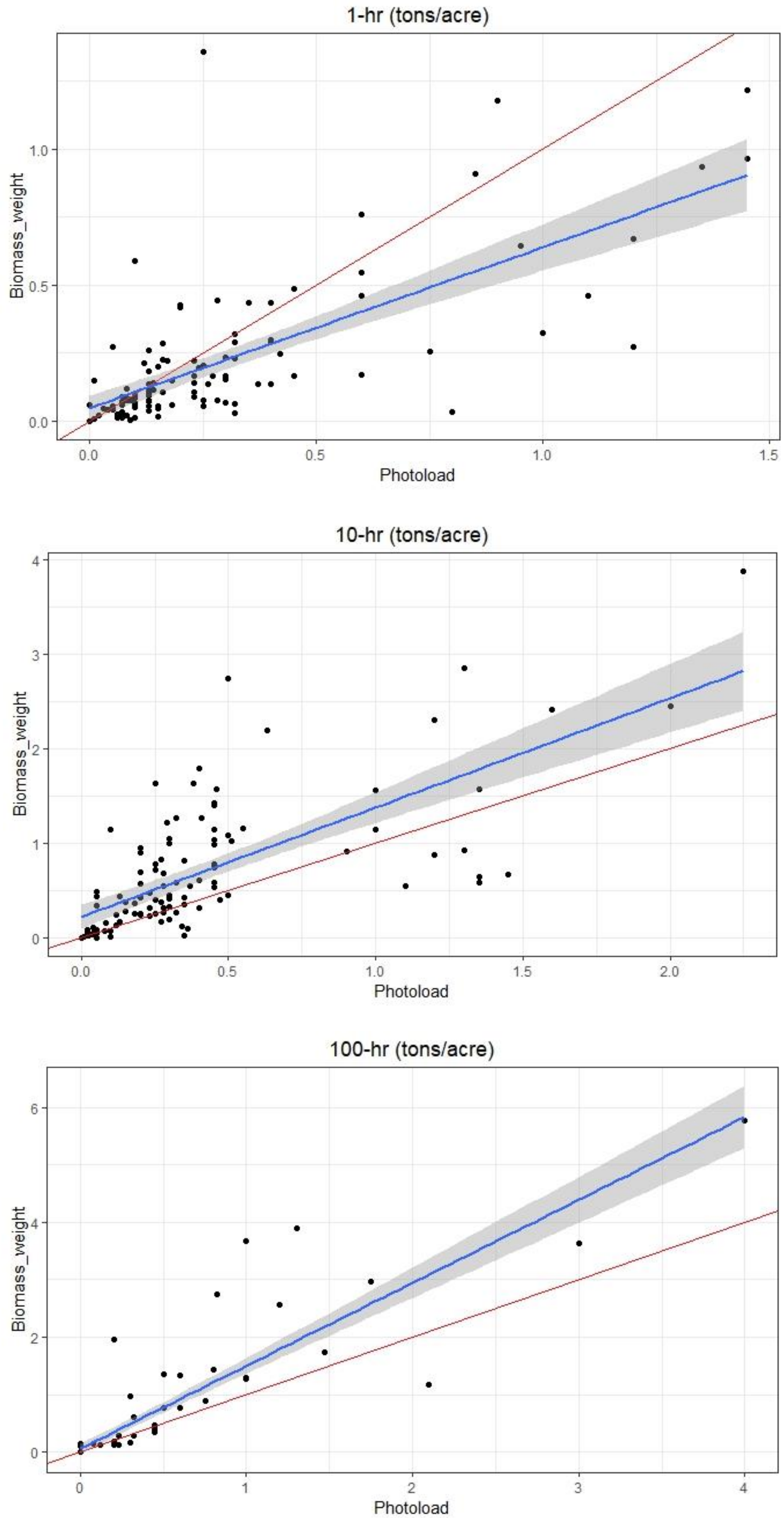

Figure 1: Regression models of photoload estimates and observed loading for each fuel size class, the shaded area represents the 95% confidence interval for the regression line. The red line is a 1:1 line shown for comparison, points above the line are underestimated observations and points below the line are overestimated observations. Regression equations are shown in Table 1.

Results and discussion

In general, our results extend those from Tinkham et al. (2016), which concluded that field based photoload estimates overestimate low fuel loadings and underestimate high fuel loadings. However, in our analyses, we treated 1-, 10-, and 100- hour fuels separately, and found that bias in estimating fuel loadings varies by fuel size class. We found that although 1-hour fuels are often overestimated by photoload sampling, 10- and 100-hour fuels were underestimated by photoload sampling. Our regression models resulted in calibration equations that can be used to refine field-based photoload estimates in montane forests of the Colorado Front Range and remove biases in photoload estimation for each woody fuel size class (Table 2; Figure 1). Forest restoration and fire hazard mitigation treatments can change surface fuels and their distribution depending on how resulting slash is treated; for example, fuel mitigation treatments that employ mastication or mulching can generate more 1- and 10- hour fuels (Battaglia et al., 2010). Photoload sampling can lead to more rapid and accurate estimation of woody surface fuels (Keane and Dickinson, 2007; Tinkham et al., 2016). However, because biases exist in visual estimation, fuels calibration equations for individual fuel size classes are critical for accurate estimation of surface fuels across different treatment types.

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