



Commentary: Large Trees Dominate Carbon Storage in Forests East of the Cascade Crest in the United States Pacific Northwest

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A Commentary on

Large Trees Dominate Carbon Storage in Forests East of the Cascade Crest in the United States Pacific Northwest

by Mildrexler, D. J., Berner, L. T., Law, B. E., Birdsey, R. A., and Moomaw, W. R. (2020). *Front. For. Glob. Change* 3:594274. doi: 10.3389/ffgc.2020.594274

INTRODUCTION

The U.S. Forest Service (USFS) recently made revisions to an interim prohibition on cutting trees ≥ 53 cm diameter at breast height (DBH) in seasonally dry, fire-prone forests of eastern Oregon. This policy change is designed to allow cutting of young (< 150 years) shade-tolerant fir ≥ 53 cm DBH to facilitate the conservation and recruitment of old (> 150 years) shade-intolerant pine and larch (United States Department of Agriculture (USDA) Forest Service, 2020). Mildrexler et al. (2020) criticize this proposal based solely on evidence that large trees (i.e., trees ≥ 53 cm DBH) store more carbon than small trees (i.e., trees < 53 cm DBH). Without any analysis of tree-, stand-, or landscape-scale carbon fluxes, Mildrexler et al. argue that forest-based climate change mitigation goals can best be served by maintaining prohibitions on cutting young trees ≥ 53 cm or even extending prohibitions to include trees as small as 30 cm DBH.

Mildrexler et al. err in assuming that prohibiting logging of relatively large but young shade-tolerant trees will enhance forest carbon storage over time in seasonally dry, fire-prone landscapes. Carbon stores in these forest communities are increasingly vulnerable to the combined effects of more than a century of fire exclusion and a warming climate (Hessburg et al., 2019). Mildrexler et al. disregard the ecological benefits of thinning projects that remove young shade-tolerant trees to enhance the resistance of old shade-intolerant trees that can store carbon over longer periods in the face of a warming climate (Henson et al., 2013; Bradford and Bell, 2017; Stephens et al., 2020). The errors, oversights, and misrepresentations in Mildrexler et al. summarized below and in **Table 1** make this study an unsuitable basis for evaluating policy change.

TABLE 1 | Summary of key errors and misrepresentations in Mildrexler et al. (2020).

Error or misrepresentation	Explanation: why this is a problem
Inconsistencies and inaccuracies in estimates of stored and removed carbon in the snow basin case study	
Estimates reported for carbon storage and removal are nearly three times greater in the manuscript than those in the Supplemental Material. Evaluation and interpretation of the case study is confounded either by errors in reporting or inadequate description of methods supporting results in Table 5.	Mildrexler et al. report estimates for carbon removed and retained using all inventory plots at the forest-scale (Table 5). They claim these results are similar to those derived using only inventory plots from within the Snow Basin project area and provide a comparison in Tables S4, S5. However, estimates in Tables S4, S5 are substantially lower than those reported in Table 5. In summary, evaluation and interpretation of the case study are confounded either by carbon estimates which vary substantially based on which inventory plots are used or erroneous information in the tables.
Misrepresenting previous research: drought-tolerance of grand fir	
Mildrexler et al. misrepresent their own research (Berner and Law, 2015), claiming that grand fir is well-adapted to drought (“grand fir radial growth was not strongly associated with variability in temperature or water variability”).	The cited paper showed that “all species, particularly fir, experienced pronounced declines in radial growth” associated with below-average water availability. Mildrexler et al. overestimate the carbon storage potential of large young fir because they assume this species will grow as well as ponderosa pine in the face of climate change-driven drought. In fact, ponderosa pine is far better suited to assimilate carbon under a warming climate (Lopushinsky, 1969; Lopushinsky and Klock, 1974).
Misrepresenting previous research: emissions from heart rot	
Mildrexler et al. assert that “a synthesis shows no evidence of carbon consequences of heart rot in grand fir (Harmon et al., 2008)” and “heart rot respiration has been estimated for another species and it had a scant contribution to ecosystem respiration (Harmon et al., 2004).”	Harmon et al. (2008) does not discuss carbon consequences of heart rot in grand fir, except to note that grand fir coarse woody debris is a third less dense (i.e., stores a third less carbon) than ponderosa pine. Harmon et al. (2004) show that failing to account for heart rot leads to a significant overestimate of carbon stores, and that the extent of heart rot is often the difference between a forest stand serving as a carbon source vs. carbon sink.
Failing to acknowledge differences in longevity between species	
Mildrexler et al. claim that prohibiting logging of young fir will result in centuries of live tree carbon storage.	Ponderosa pine and larch typically live three times longer than grand fir (Merschel et al., 2014; Johnston, 2017). Grand fir is highly susceptible to disease and drought, especially in environments where it was historically rare (Cochran, 1998; Filip et al., 2007; Hood et al., 2018). Actions that conserve old pine and larch increase the likelihood of maintaining stable carbon stores over the long term.
Misrepresenting the historical abundance of grand fir	
Mildrexler et al. claim that contemporary inventory data shows large grand fir are not over-represented on the landscape relative to historical conditions.	The preponderance of evidence, including historical records of forest structure and composition (Hagmann et al., 2013, 2014), logging records and early aerial photogrammetry (Hessburg and Agee, 2003), and dendroecological reconstruction of forest conditions and fire regimes (Merschel et al., 2014, 2018; Johnston et al., 2016; Hagmann et al., 2019; Heyerdahl et al., 2019) shows that the vast majority of grand fir basal area in eastern Oregon has developed over the last 150 years in the absence of frequent fire. FIA plot data for eastern Oregon and Washington show that the number of large larch is declining and the number of large trees of other species are increasing substantially faster than ponderosa pine (Figure 16 in Hessburg et al., 2020).
Failing to account for carbon fluxes associated with climatic and disturbance variability	
Mildrexler et al. claim that carbon stores can only decrease if policies that prohibit cutting of trees >21” are amended.	Mildrexler et al. contains no analysis of changes in carbon stocks over time, despite current and projected increases in climate change-driven drought and wildfire (Halofsky et al., 2020; Parks and Abatzoglou, 2020). Other studies of dry forest ecosystems that incorporate disturbance-mediated mortality conclude that management strategies informed by historical conditions stabilize carbon stocks given projected climate change (Liang et al., 2018; Hurteau et al., 2019; Krofcheck et al., 2019; McCauley et al., 2019).
Misrepresenting previous research: fire risk	
Mildrexler et al. state that USFS policy change will result in increased fire risk.	The studies cited in support of this claim (i.e., Lindenmayer et al., 2009; Zald and Dunn, 2018) are relevant to fire following clearcutting of productive mesic forests (e.g., western Oregon Douglas-fir forests). The preponderance of evidence from seasonally dry, fire-prone forests (e.g., Kalies and Kent, 2016) shows that fuel reduction thinning reduces fire risk and maintains ecosystem functions (Hessburg et al., 2019; Stephens et al., 2020).
Misrepresenting previous research: water stress	
Mildrexler et al. claim that removal of large but young fir will decrease water available to old-growth trees.	The studies cited in support of these claims (Kolb and Robberecht, 1996; Brooks et al., 2002; Allen et al., 2015; Kim et al., 2016; Barnosky et al., 2017; Kwon et al., 2018; Davis et al., 2019a) are specific to highly productive Douglas-fir forests of western Oregon, or make the case for removing young trees to increase water availability for old-growth pine in dry forests.
Misrepresenting previous research: microclimatic buffering	
Mildrexler et al. claim that removal of large but young fir will increase solar radiation to the forest floor, dry understory vegetation, and decrease resilience to climate change.	The literature cited in support of this claim (Chen et al., 1993, 1999; Frey et al., 2016; Davis et al., 2019b; Buotte et al., 2020) is either relevant to clearcutting of highly productive Douglas-fir forests of western Oregon or makes the case for opening up the canopy of seasonally dry forest stands to enhance native vegetation and improve stand resiliency.

(Continued)

TABLE 1 | Continued

Error or misrepresentation	Explanation: why this is a problem
Mischaracterizing wildlife and biodiversity in dry forests	
Mildrexler et al. claim that retention of all large trees in eastside forests provides the greatest benefit for wildlife habitat and biodiversity.	Studies specific to fire-prone forests find (1) the greatest number of species benefit from restoration treatments that create and maintain both closed- and open-canopy habitat types, and (2) the highest biodiversity is in stands maintained by thinning, removal of ladder fuels, and prescribed fire (e.g., Pilliod et al., 2006; Fontaine and Kennedy, 2012).
Inaccurately characterizing snag persistence	
Mildrexler et al. state that all large snags will persist for years and overestimate carbon storage potential of grand fir after death relative to other species.	Snag fall rates differ significantly by species (Dunn and Bailey, 2012). Lacki et al. (2012) found that fir snags had lower persistence than other conifer species in eastern Oregon.

MILDREXLER ET AL. MISREPRESENT FOREST ECOLOGY AND CARBON DYNAMICS IN SEASONALLY DRY FORESTS

At the heart of Mildrexler et al.'s argument is the conviction that current carbon stocks can be maintained, and even more carbon can be stored in seasonally dry forests of eastern Oregon if thinning is limited to trees <53 cm DBH (or, alternately, 30 cm DBH). This argument ignores the fact that current carbon stores in eastern Oregon forests accumulated because fire was effectively excluded from the landscape for more than a century (Parks et al., 2015; Reilly et al., 2017; Haugo et al., 2019). In particular, the number of shade-tolerant fir ≥ 53 cm DBH increased substantially over the last century as a consequence of fire exclusion (Hagmann et al., 2013, 2014; Merschel et al., 2014; Johnston, 2017; Johnston et al., 2018). Mildrexler et al. ignore research showing that dry forests have overshot their carbon-carrying capacity and that thinning treatments, although they reduce carbon stocks in the short term, will tend to stabilize carbon stocks over multi-decadal time scales in the face of a warming climate (e.g., Hurteau et al., 2019; Krofcheck et al., 2019). Mildrexler et al. assert without evidence that large shade-tolerant fir are not over-represented on the landscape and that forests of eastern Oregon have "low future climatic vulnerability." But deepening drought and increasing fire extent and severity throughout eastern Oregon (Reilly et al., 2017; Parks and Abatzoglou, 2020) have made it clear that much of the carbon currently stored on this landscape is increasingly vulnerable to loss over the next several decades if stand densities remain at their current levels (Halofsky et al., 2018; Kerns et al., 2018; Stephens et al., 2020).

The USFS's proposal to allow cutting of some large but young shade-tolerant trees is designed to restore ecosystem resilience to fire and drought and increase the resistance (and long-term carbon storage potential) of shade-intolerant old-growth trees, especially ponderosa pine. Old-growth ponderosa pine has extensive heartwood and exceptional drought, insect, and fire tolerance when freed from competition with fast-growing shade-tolerant fir with high leaf area and transpiration demands (Hessburg et al., 2020). Mildrexler et al. assert that

extant populations of young shade-tolerant fir can provide "centuries of long-term carbon storage" and that removal of relatively large young trees facilitated by Forest Service policy change represents a net emission to the atmosphere over all spatial and temporal scales. In fact, relative to the old pine and larch they endanger, large young fir that were off-limits to removal are far more prone to heart rot, which results in significant greenhouse gas emissions (Aho, 1977; Covey et al., 2012). They are also far more prone to mortality from drought, insects, and root diseases than pine. A number of studies investigating mortality of grand fir in eastern Oregon report 100% mortality of large fir over 10–20 years of observations (i.e., Cochran, 1998; Filip et al., 2007).

Throughout their paper, Mildrexler et al. assert that prohibitions on cutting large but young fir in eastern Oregon convey significant benefits to wildlife, water quality, and fire and drought resilience. But the literature cited in support of these claims either speaks to management of old-growth trees in highly productive mesic forests of western Oregon or actually makes the case for the USFS's proposal to remove large but young fir to reduce competition with fire- and drought-tolerant old-growth pine and larch. There is little doubt that conserving the most productive structurally complex older forests in western Oregon achieves carbon storage, water quality, and wildlife habitat benefits without risking uncharacteristically extensive mortality from fire and drought (Halofsky et al., 2018). But in seasonally dry forests of eastern Oregon, research demonstrates that providing a wide range of wildlife habitat, protecting old-growth trees, and enhancing stream and watershed health is best achieved by judicious removal of young trees, including large shade-tolerant trees, that established while fire was excluded from the landscape (Lehmkuhl et al., 2007; Fontaine and Kennedy, 2012; Hessburg et al., 2020).

DISCUSSION

Avoiding catastrophic effects of rising global temperatures is the most important challenge facing human civilization (IPCC, 2018). Forests have an important role in sequestering carbon to offset anthropogenic emissions. For instance, deferring harvest or increasing rotation ages in mesic forests

currently below their carbon storage capacity has tremendous potential for offsetting emissions (Hudiburg et al., 2009). But relying on seasonally dry, fire-prone stands that are currently well above historical levels of aboveground tree carbon is likely to destabilize carbon stocks and forfeit the multiple ecological benefits associated with restoration treatments, especially as the climate warms (Hurteau et al., 2016; Liang et al., 2018; Foster et al., 2020; Stephens et al., 2020). We urge policy makers to rely on comprehensive and accurate accounts of carbon dynamics when crafting policy for dry forests.

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AUTHOR CONTRIBUTIONS

JJ, RH, SS, AM, JF, and KJ contributed research and writing. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: NJ was employed by Applegate Forestry.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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