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Nutrient content of vegetation and soil of four conifer species growing under different site and competing vegetation management conditions

Carlos A. Gonzalez-Benecke [a,*], Callan F. Cannon [b], Emily C. Von Blon [a]

[a] *Department of Forest Engineering, Resources and Management, Oregon State University, Corvallis, OR 97331, USA*
[b] *USD.A. Forest Service, USA*

A R T I C L E I N F O

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A B S T R A C T

In this study we examined the long-term effects of competing vegetation control on the total nutrient content of different ecosystem components of 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing in Oregon's central Coast Range (CR) and of DF and WRC growing in Oregon's Cascade mountain foothills (CF). Nutrient content responses were evaluated under two contrasting vegetation control treatments, including the Control (no herbicide application post-planting), and VM (5 consecutive years of herbicide application post-planting). Both treatments involved a pre-planting herbicide application. The ecosystem components were divided into overstory (planted crop trees), midstory, understory, forest floor, fine roots, and mineral soil. All samples were analyzed for content (mass per unit ground area) of total carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, copper, iron, manganese, sodium, and zinc. VM effects on total plant derived nutrient masses were more prominent than differences in concentrations. Ca was the only nutrient for which all species showed higher plant derived masses in the VM condition. Plant derived tissue content of C, Cu, P, and B all tended to be higher in VM plots, with the exception of WRC plots at the CR site. This case was an outlier due to the fact that Control plots developed significantly more biomass as a result of high midstory biomass, whereas the VM plots developed relatively little midstory and crop tree biomass. There were few differences in soil nutrients content between species and treatments, and those that were significant were unable to be explained by differences in uptake by plant species. Notably, total soil N of WRC at the CR site was significantly lower for VM plots. This may indicate the potential for VM applied to a slow growing species, such as WRC, to reduce ecosystem retention of N. With the exception of C and N, total soil nutrient reserves were orders of magnitude greater than total plant derived masses. This indicated that there is low probability of an adverse effect of VM on soil nutrient stores.

1. Introduction

Silviculture has the potential to change the way a forest uses nutrients, such as through changing nutrient distribution between pools or the amount stored in different tissue types. Silviculture can affect nutrient content by altering the concentration in a given tissue and/or by altering the mass of a given tissue. Forest vegetation management (FVM), for example, reduces the amount of nutrients stored in competing vegetation and allows the system to reallocate these nutrients to crop trees (Devine et al., 2011; Littke et al., 2020a). It also changes the allometry of crop trees, which will affect the way they distribute nutrients to different tissues (Gonzalez-Benecke et al., 2018). Soil preparation, FVM, and fertilization in nutrient-deficient soils typically lead to increased biomass, and therefore an increase in tissue nutrient content (Fox et al., 2007). FVM is an important silvicultural tool particularly because it increases seedling growth rates and survival, while its effects on seedling tissue concentration are equivocal (Cannon et al., 2021). In young plantation stands in the U.S. Pacific Northwest, crop trees associated with FVM had larger stem, branch, and foliage biomass compared to trees in control plots with similar diameter at breast height (Maguire et al., 2009; Petersen et al., 2008; Flamenco et al., 2019; Littke et al., 2020b).

Plants distribute nutrients throughout their tissues in order to satisfy their physiological needs. Measures of tissue nutrient content are

* Corresponding author.
E-mail addresses: carlos.gonzalez@oregonstate.edu (C.A. Gonzalez-Benecke), callanfcannon@gmail.com (C.F. Cannon), emily.vonblon@oregonstate.edu (E.C. Von Blon).

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important for understanding the ways an ecosystem uses nutrients. They have been used to calculate nutrient budgets, which can contribute to measuring processes such as how a forest ecosystem cycles nutrients internally, how they may differ between stands, or how stand nutrient storage changes with age (Sollins et al., 1980; Compton and Cole, 1998). They have been used to estimate harvest removals from a system under different harvest scenarios. They can also be used to quantify total soil nutrient reserves, which can help with management decision-making (Augusto et al., 2003; Callesen et al., 2016; Vadeboncoeur et al., 2014).

Changes in the plant community can alter ecosystem nutrient use. Conversion of a *Picea abies* plantation to various different species showed that each species utilized nutrients differently such that there were different trends for each species and nutrient (Carnol and Bazgir, 2013). The study found that reforestation with *Sorbus aucuparia* increased soil exchangeable calcium magnesium and potassium (Carnol and Bazgir, 2013). FVM inherently alters the structure and composition of these plant communities, and thus affects the nutrients storage capabilities and nutrient cycling within a stand. Slesak et al. (2009) found that VM increased dissolved organic N and nitrate concentration. Since these N species are mobile in soils, this has the potential to increase nutrient leaching, meaning that plant community structure affects the ability of the site to retain nutrients. Similarly, after disturbance, when there is a reduction in living plants at a site, nutrients are more susceptible to leaching as there are fewer primary producers to immobilize them.

Studies of FVM and crop tree nutrient content typically only focus on young, generally 5-year-old, Douglas-fir and loblolly pine. A study of 13-year-old loblolly pine demonstrated higher foliar potassium and nitrogen mass with herbaceous vegetation control but no difference in foliar phosphorous, calcium, and magnesium mass (Miller et al., 2006). A study of young Douglas-fir seedlings at the Long Term Soil Productivity (LTSP) sites in Mollala, OR, Matlock, WA, and Fall River, WA, showed that FVM increased crop tree biomass as well as the nitrogen content of the foliage and whole tree (Devine et al., 2011; Slesak et al., 2010). At age 15 years old, the improvement in stand volume growth had decreased since the previous measurements at age 5 years old at the more productive Fall River, WA site, which may be a result of higher soil nutrient demands during canopy closure, with a similar response being hypothesized for the Mollala, OR and Matlock, WA sites when entering the canopy closure stage (Littke et al., 2020b). A different study on 5-year-old Douglas-fir found that foliage concentrations of N, P, K, S, Ca, Mg remained largely the same, but changes in aboveground biomass led to a greater than two fold increase in macronutrient content (Petersen et al., 2008). Generally, all these studies found that seedlings grown in treated plots attained significantly larger biomass, leading them to find that total nutrient content of trees was greater when growing in the absence of competing vegetation.

Management effects on total soil nutrient content are similar to soil nutrient concentrations effects since silvicultural prescriptions generally do not increase soil mass or bulk density (soil compaction upon harvesting being an exception). Generally, when there are differences in nutrient content, they tend to be in the top 0.2 m of soil and more pronounced at poor quality sites (Slesak et al., 2011). Studies of soil nutrients often focus on N or P but will occasionally investigate exchangeable cations. LTSP sites in Oregon show that soil nutrients (exchangeable Ca, Mg, K, and total N) tend to increase 10 to 15 years after planting in the top 0.3 m of soil. However, the increase is greater when there is no vegetation control after planting (Slesak et al., 2016; Littke et al., 2020b). Studies from different sites and with different species yield different results. A study looking at different P pools showed that at one site, when there was a detectable difference in P concentrations of any pool, concentrations were higher with no annual vegetation control while the other site showed the opposite trend (DeBruler et al., 2019). A similar study from the Fall River LTSP site in WA showed that total soil N concentrations in the top 0.15 m of soil decreased 10 years after planting (Knight et al., 2014). One study of loblolly pine conducted at mid-rotation found that all available soil nutrients declined over time, but this decline was greater for C, N and Ca (Miller et al., 2006). A study of jack pine, red pine, western white pine and black spruce showed that changes to soil nutrients caused by FVM vary by nutrient and species (Hoepting et al., 2011). In a study of loblolly and slash pine at rotation age, Vogel et al. (2011) found that competing vegetation control reduced fine root biomass in deep soil layers, decreased soil carbon, and increased N in the mineral soil.

Most of these studies investigate young stands of only one or two crop species. They also typically only focus on a few plant/soil pools (such as crop tree foliage or soil to a certain depth) and a few nutrients (typically N, P, K and occasionally Ca and Mg). In this study we will investigate how FVM affects the nutrient mass of a wide variety of plant and soil pools of multiple conifer species (Douglas-fir, western hemlock, western redcedar, and grand fir) in two important timber producing ecoregions in Oregon (the Oregon Cascade mountain foothills and the Oregon Coast Range). We will combine this mass information to also investigate how treatment affects the nutrient masses of all plant derived and soil derived pools as a whole.

The overarching goal of this project is to understand how intensive silvicultural practices affect long-term site quality. The specific objective of this study is to construct nutrient budgets for stands of different species and sites and to compare total ecosystem, plant derived, and soil nutrient masses between contrasting regimes of FVM. We hypothesize that midstory trees increase the nutrient storage capacity of conifer dominated ecosystems because they store a large quantity of nutrients in their foliage. If this is true, total ecosystem nutrient content will be higher in plots that did not receive herbicide treatment and where an understory and midstory have developed.

2. Materials and methods

2.1. Description of sites

The Coastal Range (CR) site is located near Summit, OR approximately 40 km from the coast (44.62°N, 123.57°W). The site was planted in year 2000 and experiences a mean annual temperature of 11.1 °C and average annual rainfall of 1707 mm. The CR site was planted with Douglas-fir (DF, *Pseudotsuga menziesii* var. *menziesii* (Mirbel) Franco) and western hemlock (WH, *Tsuga heterophylla* (Raf.) Sarg.) (four replicates each), as well as grand fir (GF, *Abies grandis* (Dougl. ex D. Don) and western redcedar (WRC, *Thuja plicata* Donn ex D. Don) (three replicates each). The soil at the CR site is fine and loamy (Flamenco et al., 2019). The soils are part of the Preacher-Bohannon complex, which is derived from siltstone and sandstone. This soil complex is classified as an Andic Dystrudept, meaning that while it is not an Andisol, it has high aluminum and iron activity (Soil Survey Staff, 2015).

The Cascade Foothills (CF) site is located near Sweet Home, OR (44.48°N, 122.73°W). The site was planted in year 2001 with DF and WRC (four replicates each). The site has a mean annual temperature of 12.4 °C and an average annual rainfall of 1179 mm. The soil at this site is a silty clay loam (Flamenco et al., 2019). Soils at the CF site are from the Bellpine series, which is derived from sedimentary rock (Soil Survey Staff, 2015). Soils of this series are classified as Xeric Haplohumults, indicating an Ultisol with high organic matter content that experiences seasonal drought. These soils are well drained and characterized by a more xeric moisture regime than the CR site. Similar to the CR site, these soils are derived from sedimentary bedrock. However, tuff and mafic intrusions will lend different chemical characteristics to these soils (Soil Survey Staff, 2015). This site was formerly agricultural land that was not sufficiently productive.

On a relative basis, the CF site is less productive than the CR site, with Douglas-fir Site Index values of 38.1 and 44.8 m, respectively. Furthermore, at age 16 years, aboveground tree biomass was 76.6 and 95.3 Mg ha^{-1} at the CF and CR sites, respectively (Flamenco et al., 2018).

2.2. Study design

A randomized complete block design with eight FVM treatments was implemented at each of the two sites. The eight different FVM treatments consisted of spring release applications that differed in the number and timing of herbicide treatments applied during the first 5 years after planting (Maguire et al., 2009). Similar to Flamenco et al. (2019) and Cannon et al. (2021), for this study we used only two treatments: Control (only pre-planting vegetation control) and VM (5 consecutive years of spring release herbicide treatment). Each treatment plot was 24.4 m x 24.4 m (0.06 ha) in size and was planted with 64 seedlings (8 rows of 8 trees) with 3 m x 3 m spacing, resulting in a planting density of 1111 trees ha^{-1}. Measurement plots consisted of the internal six rows of six trees allowing for a one tree buffer on all sides. All plots were planted with a single tree species, and the experimental unit was the plot. All DF plots received pre-commercial thinning at age 12 years to reduce stocking by 25% and thinning residues were left on site.

The ecosystem was divided into soil pools and plant derived pools. The plant derived pools were broken down into overstory (planted crop trees), midstory (hardwoods and natural conifer regeneration), understory (shrubs, grasses, forbs, ferns and moss) and forest floor (including coarse woody debris). The overstory was divided into foliage, live branches, stemwood, stembark, and fine roots. The midstory was broken down into foliage and bole (stemwood and stembark). The soil was divided into four layers (0–0.2 m, 0.2–0.4 m, 0.4–0.6 m, and 0.6–1.0 m).

2.3. Soil characterization

Soil samples were taken during June 2019. Soil mass for each layer was computed from the bulk density (methods described below) and calculated volume of the layer (assuming a rectangular prism with two faces 0.2 ha in size and a depth of either 0.2 or 0.4 m). Mineral soil samples were collected at four depth increments: 0–0.2 m, 0.2–0.4 m, 0.4–0.6 m, and 0.6–1.0 m. The top 0.2 m was sampled in spring 2017 using a 5-cm diameter PVC core (6 samples per plot; Flamenco et al., 2019). The lower layers were collected in spring 2019 with one sample per layer per plot using 5 cm × 5 cm soil cores (AMS, bulk density soil sampling kit). Soil samples were dried at 105 °C for at least 72 h and ground to pass a 2 mm sieve. Dry soil mass was measured and used to calculate the bulk density of the layer. Soil pH was measured in 1:1 soil to water ratio using a Hanna Instruments HI5522. Four plots from each site were chosen for texture analysis. In order to measure soil texture, 50 g of soil was resuspended in a 1% sodium metaphosphate solution by shaking for 4 h and resuspending the soil mixture in a 1 L graduated cylinder. Solution density was measured using a hydrometer at 45 s and again at 7.5 h. These densities were used to calculate percentages of sand, silt, and clay according to Miller et al. (2013).

2.4. Biomass calculations

Overstory (crop tree) biomass was computed using tree inventory (DBH and height) data at age 19 years (CR site in January 2019; CF site in January 2020) and the species and site-specific biomass functions reported in Gonzalez-Benecke et al. (2018). Midstory biomass was computed using tree inventory (DBH) data from July 2019, which recorded all non-crop trees that were greater than 10 cm in DBH as well as recorded those with a DBH of less than 10 cm sampled from six 4 m^2 subplots randomly placed within each treatment plot. The species-specific biomass functions are reported in Flamenco et al. (2019). Species specific biomass functions were also used to calculate midstory foliar biomass for the main four midstory species: red alder (*Alnus rubra* Bong.), bigleaf maple (*Acer macrophyllum* Pursh.), cascara buckthorn (*Rhamnus purshiana* Don.), and Oregon bittercherry (*Prunus emarginata* (Dougl. ex Hook.) Eaton) (Busing et al., 1993; Flamenco et al., 2019; Snell and Little, 1983). Since species specific foliage biomass equations were not available for Oregon bittercherry, an equation for pin cherry (*P. pensylvanica* L.f.) was used. Forest floor biomass was previously sampled during the summer of 2016 and 2017 at the CR and CF sites, respectively, and was reported by Flamenco et al. (2019). This sampling process involved using a 0.6 × 0.6 m frame in the center of the six midstory subplots per measurement plot; the vegetation cover % of each life form was estimated visually, all vegetation within the subplot was clipped, and the forest floor, including litter, duff, and coarse woody debris, was raked to the bare mineral soil. Vegetation less than 1.37 m in height that came over the top of the subplot was also clipped. Understory biomass was estimated from direct measurements of vegetation cover % and height from the six 0.36 m^2 subplots per treatment plot during July 2019, using the equations reported by Guevara et al. (2021). Understory and forest floor samples were dried at 75 °C for at least 72 h. The forest floor samples and each understory life form were then weighed separately.

Fine roots were collected from each soil sample using a 2 mm sieve. Fine root biomass for each layer was calculated by scaling the mass of fine roots collected from the soil cores proportionally to the volume of the layer determined using a rectangular prism. This biomass was summed for all layers in a plot to calculate total fine root biomass. This biomass was partitioned into crop tree fine roots and vegetation fine roots allometrically. This was done by calculating a ratio between crop tree basal area and fine root biomass for the VM plots (where vegetation fine roots were assumed to be negligible) and applying this ratio to the Control plots- where any remaining fine root biomass was attributed to competing vegetation (understory and midstory).

2.5. Nutrient budget calculations

Total nutrient concentrations for each pool in each plot was previously reported in Cannon et al. (2021). To determine nutrient concentrations, stemwood, bark, branch and foliage samples were collected from four trees, selected to represent the range of stem diameters found at each site, for each crop species and each treatment at each site (Gonzalez-Benecke et al., 2018). Given that the two sites had the same dominant midstory species present, midstory foliage and stemwood was only sampled at the CR site for four midstory trees for each species. Understory, forest floor and fine roots were collected from six 0.6 × 0.6 m subplots per treatment plot and sampled using the methods described previously. One mineral soil sample at four depths per plot were taken using the procedure described previously. The six subsamples per treatment plot were combined for analysis and prepped for nutrient extraction at the Central Analytical Laboratory at Oregon State University.

To conduct the total nutrient concentration analysis, the plant samples were dried at 65 °C until the weight of the samples remained constant, and were then grounded to pass through a 0.425 mm sieve. The plant tissue samples were placed in quartz tubes at 580 °C for overnight combustion. The samples were then extracted in in 20% v/v HCl for 15 min, diluted at an equal ratio of 1:1 with distilled water, and then filtered before being stored at 4 °C. Once these preparations were made, the total soil nutrients were extracted through the microwave digestion process, during which the samples were in a solution of 70% HNO3 and kept at 175 °C for 4.5 min in an Anton-Paar MicrowaveGO. These digested samples were again diluted at an equal ratio of 1:1 with distilled water and filtered before being stored at 4 °C. C, N, and S concentrations were determined by undergoing dry combustion using an Elementar vario MACRO cube, while all other nutrients, including P, K, Mg, Ca, B, Cu, Fe, Mn, Na, and Zn, were determined through analysis of extracts using an Agilent ICP-OES 5110. These methods are defined in Cannon et al. (2021).

Nutrient concentrations were multiplied by the calculated biomass of each pool in each plot (see above) to determine the total mass of each nutrient in a given pool and plot. Average values for each site, species, and treatment were computed by averaging across replicates. For each site, species, treatment, and nutrient, calculated nutrient masses of plant derived nutrient pools were summed, as were total soil nutrient pools. Note that soil nutrient pools were for total nutrients rather than exchangeable/plant accessible nutrients. We recognize that our focus on total nutrient pools may mask relatively small changes in plant available pools that are important to short-term effects on stand growth.

ICP analysis failed to detect K and Na in the stemwood samples of all species of overstory and midstory trees (Cannon et al., 2021). The limit of detection is 2 ppm for Na and 0.04% K (400 ppm) in undiluted tissue. Since it is known that actual concentrations of these nutrient are non-zero, they were assumed to be a fixed value for all species. Nutrient budgets were constructed assuming stemwood concentrations of 0.5 ppm, 1 ppm and 1.5 ppm for Na and 0.01%, 0.02% and 0.03% for K. For each assumption, treatment differences for total plant derived Na and K mass were analyzed (see next section for details) in order to determine how sensitive the analysis was to this parameter. Since there was no statistical difference (Appendix Table A.1), the largest concentrations (1.5 ppm Na and 0.03% K) were used for further analysis.

2.6. Statistical analysis

The Statistical Analysis Software version 9.4 (SAS Institute Inc. Cary, NC) was used for all statistical analysis. Analysis of variance, including Tukey multiple comparisons tests, was used to test the effects of site, species and treatments on all soil and plant derived pools (PROC MIXED, SAS Institute Inc. Cary, NC). SigmaPlot version 14 (Systat Software, Inc. San Jose, CA) was used to create all figures. All P-values for DF and WRC as well as all Site parameters and interactions (Site x Trt, Site x Spp, and Site x Spp x Trt) were calculated from a mixed linear model using a reduced dataset excluding WH and GF plots. All P-values for WH and GF, as well as Spp, Trt, and Spp x Trt parameters, were calculated from a mixed linear model using a reduced dataset excluding all plots from the CF site. The level of significance was defined as $\alpha = 0.05$.

3. Results

3.1. Stand inventory and soil properties

A summary of stand attributes at age 19 years is provided in Table 1. In general, the VM treatment increased the mean height, quadratic mean diameter (QMD, cm) and basal area (BA, m^2 ha^{-1}) of crop trees at both sites. For example, DF in the VM treatment were on average 1 and 2.3 m taller than the Control treatment for the CR and CF sites, respectively. Although the BA of crop trees was larger in the VM treatment (reaching 42.5 m^2 ha^{-1} for WH and GF), the Control treatment tended to have much higher midstory BA, ranging between 16.1 to 29.3 m^2 ha^{-1} at the CR site and 2.7 to 4.5 m^2 ha^{-1} at the CF site. There was no midstory for any of the VM treatment plots with the exception of WRC at the CR site, which had a BA of 0.7 m^2 ha^{-1}.

There was a trend for the stocking of plots with VM to be higher than Control plots. This effect was particularly strong for WRC at the CF site, which averaged 344 and 935 trees ha^{-1} for the Control and VM plots, respectively. VM treatment effects were significant for all stand metrics (TPH, Height, QMD and BA; Table 4). Plant derived biomass for each treatment is plotted in Fig. 1.

Midstory components differed between species and sites. DF plots did not tend to develop a midstory without VM, though there was some development on plots at the CF site. WH plots accumulated dense conifer regeneration in Control plots, especially ones that were close to the adjacent mature DF stands, though they also contained various hardwood species. GF Control plots developed a similar BA of midstory species compared to WH, but this was mostly composed of native broadleaf species with less conifer regeneration. Midstory development in WRC plots had remarkably different trajectories at the two different sites. At the CF site, there was very little midstory development despite the significant crop tree mortality. At the CR site, there was less crop tree mortality, however there was significant, dense midstory composed largely of broadleaf species.

Soil physical and chemical properties are listed in Table 2. Soils at both sites were acidic, with pH averaging 4.85 at the CR site and 5.05 at the CF site for all depths, and no significant differences across species or treatments. Soil bulk density did not vary by treatment but did vary significantly in the 0.4–0.6 m layer for GF, averaging 0.928 g cm^{-3}, in comparison with a mean value of 0.790 g cm^{-3} for the other three species ($P = 0.017$; Table 4).

3.2. Nutrient budget summary

A summary of ANOVA tables, including P-values for all effects for macro and micro nutrient mass in all ecosystem pools, can be found in Appendix Tables A2-A14. Similarly, while several nutrient budgets will be highlighted in this manuscript, all budgets can be found in Appendix Figures A1-A14. Masses of each nutrient stored in each tissue for all sites, species, and treatments can be found in Appendix Tables A15-A40. In general, macro nutrient masses stored in aboveground crop tree tissues (specifically foliage, branches, bark, and stemwood) displayed a significant Spp x Trt effect, largely because the biomass of crop trees responded to treatment differently for each species (data not shown).

Average nutrient content (kg ha^{-1}) of total plant derived (calculated as the sum of crop tree, midstory, understory, and forest floor masses) and soil (calculated as the sum of all soil depths masses) nutrient mass is shown in Table 3. Detailed analysis for C, N, P, K, B and Fe in all ecosystem pools are shown later in this manuscript. In general, across sites, species, and VM treatment, the total soil nutrient reserves are 10 to 1000 times greater than the amount stored in plant tissue (excluding C,

Table 1
Average trees per ha (TPHA, ha^{-1}), mean height (height, m), quadratic mean diameter (QMD, cm), crop tree basal area (BA, m^2 ha^{-1}) and midstory basal area (BA, m^2 ha^{-1}), for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) planted stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Control: no post-planting vegetation control, VM: sustained vegetation control for first 5 years post-planting. For each site, letters within a column represent significant differences at $\alpha = 0.05$.

Site	Species	Treatment	TPHA (ha^{-1})	Height (m)	QMD (cm)	Crop tree BA (m^2 ha^{-1})	Midstory BA (m^2 ha^{-1})
CR	DF	Control	681c	17.1 a	21.7 ab	25.1 b	0.0 d
		VM	725c	18.1 a	23.3 a	31.0 bc	0.0 d
	WH	Control	868 abc	13.5 bc	16.9c	19.4c	16.1 b
		VM	1032 a	17.2 a	22.9 a	42.6 a	0.0 d
	WRC	Control	748 bc	6.2 d	10.4 d	7.0 d	29.3 a
		VM	967 ab	10.7c	17.9 bc	24.0 bc	0.7c
	GF	Control	907 abc	11.8c	15.0 cd	16.5 cd	17.7 b
		VM	987 ab	15.6 ab	23.4 a	42.5 a	0.0 d
CF	DF	Control	696 a	15.7 b	19.4 b	20.5 b	4.5 a
		VM	718 a	18.0 a	23.2 a	30.3 a	0.0 b
	WRC	Control	344 b	9.3 d	17.6c	8.0c	2.7 a
		VM	935 a	10.3c	16.9c	20.9 b	0.0 b

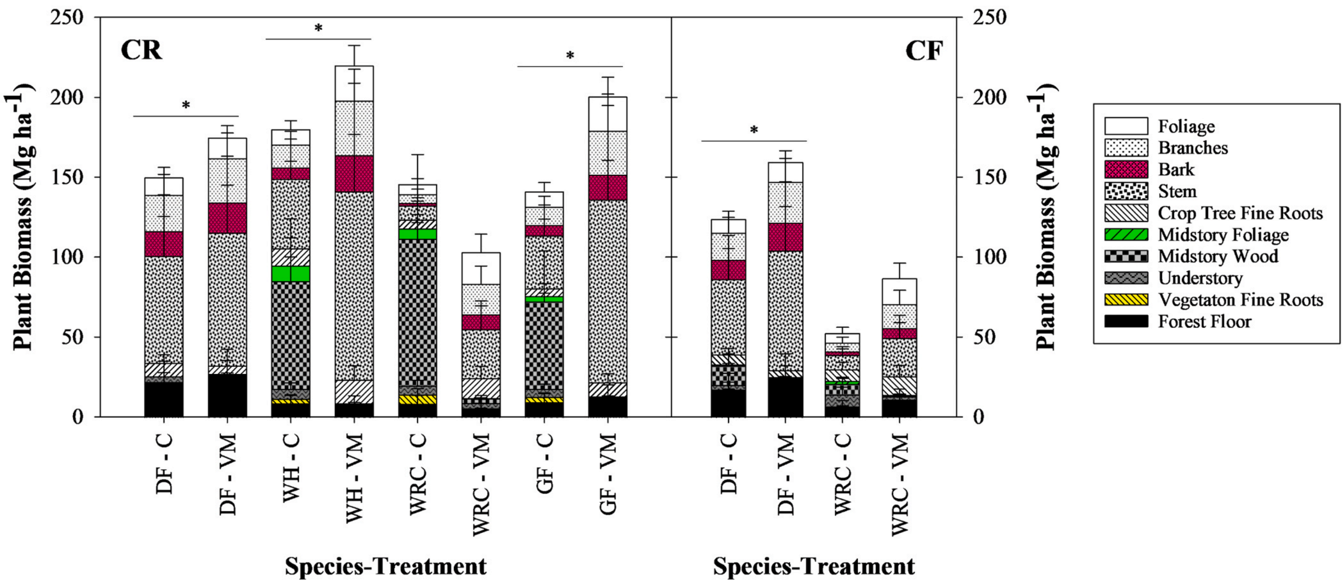

Fig. 1. Average biomass (Mg ha^{-1}) of plant derived pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

Table 2
Average pH, bulk density, and particle size distribution of four layers of soil (0–0.2 m, 0.2–0.4 m, 0.4–0.6 m, and 0.6–1.0 m) for study sites in the Oregon Coast Range (CR) and Cascade Foothills (CF). Standard errors are included in parentheses.

Site	Depth	pH	Bulk Density* (g cm-^{3})	Sand (%)	Clay (%)	Silt (%)
CR	0-0.2 m	4.71 (0.04)	0.704 (0.013)	30.4 (4.4)	38.0 (4.7)	31.6 (3.6)
	0.2-0.4 m	4.88 (0.04)	0.790 (0.015)	21.3 (5.4)	48.9 (7.3)	29.8 (2.6)
	0.4-0.6 m	4.92 (0.03)	0.822 (0.018)	14.6 (2.8)	60.4 (4.6)	25.0 (3.1)
	0.6-1.0 m	-	0.947 (0.103)	15.9 (4.4)	58.1 (3.9)	26.0 (2.2)
CF	0-0.2 m	5.19 (0.07)	0.706 (0.021)	21.8 (1.8)	34.3 (1.7)	43.9 (0.4)
	0.2-4 m	5.05 (0.07)	0.738 (0.022)	13.9 (1.5)	42.6 (1.9)	43.5 (0.8)
	0.4-6 m	4.81 (0.05)	0.814 (0.019)	14.0 (2.3)	40.9 (2.6)	45.1 (2.3)
	0.6-1.0 m	-	1.013 (0.089)	17.0 (3.0)	43.5 (2.7)	39.5 (0.6)

* : Fine fraction (<2 mm) bulk density.
pH for 0.6-1.0 m layer was not determined.

which is not taken up via plant roots and averaged 41.5%). On average, the percentage of total nutrients stored in plant tissue of total nutrient stored in soil averaged 5.92%, 0.17%, 2.37%, 0.39%, 4.8%, 0.28%, 0.27%, 0.02%, 0.17%, 0.52% and 0.25% for N, P, K, Mg, Ca, B, Mn, Fe, Cu, Na and Zn, respectively.

A summary of the ANOVA tables for the effects of site, species, treatment, and their interactions on total plant derived and total soil nutrient mass is shown in Table 4. For simplicity, this table only looks at total plant derived nutrients (calculated as the sum of crop tree, midstory, understory, and forest floor masses) and total soil derived nutrients (calculated as the sum of all soil depths masses). Total plant derived mass of carbon, Mg and S had a Site x Spp x Trt interaction, suggesting that the effect of VM on storage of these elements varies widely with site and crop species. Total plant derived masses of P displayed a significant treatment effect only for WH and GF. VM effect on K was only significant for GF. B, Mn, Cu, and Zn were the only micronutrients that displayed a significant treatment effect, though effect varied by species. Ca was the only nutrient that showed consistent differences across species (no Spp x Trt interaction, Table 4). Ca was the only nutrients to be affected by VM independent of site and species. With the exception of C, N and Zn, there was a significant effect of site on total soil nutrient mass (soil S masses were not quantified in this study). The only nutrient where total soil nutrient mass varied by treatment was Mg (Table 4).

3.3. Carbon budget

Fig. 2 displays the carbon mass at age 19 years. VM plots had a significantly higher mass of carbon stored in plant derived tissues across species ($P = 0.003$). The only exception to this was WRC at the CR site; crop tree growth was reduced, but the midstory contained substantial biomass (difference not significant, $P = 0.102$). In WRC Control plots, the midstory and understory contributed 75% of the total carbon mass at the CR site and 32% at the CF site. Due to this, the carbon mass of the Control treatment was greater than the VM treatment at CR, but the opposite was true at CF, although these differences were not significant. In Control plots of GF and WH, the midstory and understory contributed around 47% of total carbon mass. Soil carbon stocks were generally not significantly affected by treatment or site across all species ($P = 0.332$). The exception was WRC, where VM plots showed reduced total soil carbon mass ($P = 0.018$).

Table 3
Average nutrient content (kg ha^{-1}) of plant derived and soil for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: No post-planting vegetation management (Control), and 5-years of post-planting vegetation management (VM).

			DF		WRC		WH		GF	
Site	Nutrient	Pool*	Control	VM	Control	VM	Control	VM	Control	VM
CR	C	Plant	66,621.2	79,525.8	65,446.8	46,384.1	81,670.6	101,809.9	62,472.6	91,719.2
		Soil	155,931.9	149,564.0	174,523.5	147,099.6	147,304.8	162,449.2	193,736.5	166,780.9
	N	Plant	604.7	687.2	651.3	487.5	735.3	596.4	579.1	684.2
		Soil	9506.8	8859.2	10,548.0	8730.5	8250.2	9071.3	11,663.0	9973.8
	P	Plant	74.3	79.5	72.7	56.5	113.2	116.9	76.3	104.0
		Soil	32,481.0	32,064.3	38,754.9	40,669.1	39,350.0	37,657.3	41,366.2	44,789.0
	K	Plant	264.2	245.6	232.8	165.6	329.1	289.4	256.6	354.4
		Soil	12,862.2	13,086.3	12,456.5	14,244.6	10,406.0	11,015.9	13,803.3	14,803.9
	Mg	Plant	80.0	71.0	100.6	67.5	113.0	80.2	90.5	93.6
		Soil	23,378.5	24,620.1	20,360.0	24,900.4	19,368.6	21,576.8	25,729.4	26,206.9
	Ca	Plant	463.9	459.1	519.3	673.7	480.5	554.4	590.2	810.0
		Soil	6905.3	6442.9	7309.4	5478.5	5056.1	5050.6	9896.3	7642.1
	S	Plant	95.9	109.8	145.0	59.9	143.2	107.4	133.1	103.5
	B	Plant	1.0	1.1	1.0	0.9	1.4	1.5	1.1	1.6
		Soil	272.5	300.1	297.3	307.7	330.7	315.1	285.0	318.9
	Mn	Plant	21.4	25.3	9.9	11.0	30.0	62.0	21.2	35.4
		Soil	4742.1	5511.7	7480.9	8020.1	5842.8	5063.2	6399.9	8119.0
	Fe	Plant	45.3	42.4	35.1	31.6	38.9	33.7	33.9	33.1
		Soil	150,072.9	161,558.7	150,330.5	157,441.3	166,736.8	163,494.5	158,991.2	172,073.6
	Cu	Plant	0.4	0.4	0.4	0.3	0.5	0.6	0.4	0.6
		Soil	191.6	204.1	199.1	224.6	192.6	202.5	212.2	221.3
	Na	Plant	12.7	11.0	6.4	5.9	8.1	8.7	5.4	6.7
		Soil	1359.7	1588.1	1336.3	1434.7	1277.4	1320.0	1624.4	1501.8
	Zn	Plant	1.5	1.6	0.9	0.9	1.3	1.2	1.2	2.0
		Soil	437.1	482.7	443.3	499.8	479.1	471.8	567.6	571.6
CF	C	Plant	56,444.1	74,402.3	22,479.1	36,790.6				
		Soil	126,353.6	162,871.8	164,488.6	142,188.0				
	N	Plant	517.7	596.4	332.5	412.9				
		Soil	8923.9	10,752.2	10,921.0	9026.3				
	P	Plant	70.3	79.3	39.5	49.1				
		Soil	61,714.2	58,691.4	56,619.7	56,363.4				
	K	Plant	260.2	241.3	166.5	180.6				
		Soil	5264.2	5455.0	6779.3	5966.9				
	Mg	Plant	63.8	60.1	48.1	50.4				
		Soil	11,144.5	12,066.2	11,805.6	13,150.0				
	Ca	Plant	437.2	505.1	385.4	623.4				
		Soil	19,834.5	19,461.3	21,106.2	21,162.2				
	S	Plant	82.2	92.0	37.1	48.9				
	B	Plant	1.2	1.3	0.8	1.0				
		Soil	636.6	624.9	622.9	630.9				
	Mn	Plant	29.0	36.9	16.6	20.9				
		Soil	12,371.4	16,058.0	19,133.1	18,579.9				
	Fe	Plant	39.4	44.7	33.1	39.4				
		Soil	203,747.3	207,794.4	207,274.9	209,743.9				
	Cu	Plant	0.4	0.5	0.2	0.3				
		Soil	274.6	366.5	342.8	324.0				
	Na	Plant	4.8	5.5	3.7	3.6				
		Soil	1044.0	1061.3	1048.9	1178.2				
	Zn	Plant	1.2	1.6	0.8	0.9				
		Soil	430.4	468.6	484.8	554.5				

* : Plant is plant derived matter (sum of crop trees, midstory, understory, and forest floor) and Soil is total soil pool (0–1 m)

Table 4

Results of ANOVA test for stand characteristics, nutrient pools of plant derived matter, and soil characteristics for 19-year-old planted stands of Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Stand characteristics include: stand trees per hectare (TPHA), mean height, basal area (BA) and quadratic mean diameter (QMD). Nutrient pools include plant derived matter (sum of crop trees, midstory, understory, and forest floor) and total soil (0–1 m). Soil characteristics include the bulk density for the top three layers (0–0.2 m, 0.2–0.4 m and 0.4–0.6 m). Significant differences are highlighted in bold.

Stand Characteristic		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
TPHA		**0.031**	**0.012**	**< 0.001**	**0.026**	0.071	**0.002**	**0.012**
Height		0.252	**< 0.001**	**< 0.001**	**0.008**	0.039	0.095	**< 0.001**
BA		**0.016**	**< 0.001**	**< 0.001**	0.444	0.881	**< 0.001**	0.104
QMD		0.999	**< 0.001**	**< 0.001**	**0.001**	0.036	0.101	**< 0.001**
Nutrient	**Pool***	**Site**	**Spp**	**Trt**	**Site*Spp**	**Site*Trt**	**Spp*Trt**	**Site*Spp*Trt**
C	Plant	**< 0.001**	**0.048**	**0.003**	**0.013**	**0.003**	**0.001**	**0.018**
	Soil	0.469	0.403	0.332	0.975	0.198	0.501	0.305
N	Plant	**0.012**	0.732	0.341	0.282	0.075	**0.013**	0.067
	Soil	0.445	0.087	0.161	0.802	0.316	0.341	0.287
P	Plant	**0.009**	**0.002**	**0.045**	**0.027**	**0.036**	**0.002**	0.105
	Soil	**0.002**	0.256	0.835	0.340	0.735	0.964	0.975
K	Plant	0.343	**0.015**	0.654	0.491	0.123	**0.019**	0.120
	Soil	**< 0.001**	0.052	0.323	0.726	0.261	0.937	0.272
Mg	Plant	**0.001**	0.196	**0.001**	0.080	**0.004**	**0.021**	**0.020**
	Soil	**< 0.001**	**0.018**	0.051	0.254	0.369	0.537	0.461
Ca	Plant	0.215	**0.011**	**0.016**	0.132	0.222	0.245	0.930
	Soil	**< 0.001**	0.071	0.205	0.688	0.817	0.749	0.833
S	Plant	**0.001**	0.703	**0.013**	**0.024**	**0.005**	0.069	**0.003**
B	Plant	0.211	**0.004**	**0.002**	0.060	0.155	**0.005**	0.123
	Soil	**< 0.001**	0.701	0.436	0.814	0.779	0.728	0.803
Mn	Plant	**< 0.001**	**< 0.001**	**< 0.001**	0.709	0.288	**0.001**	0.912
	Soil	**< 0.001**	0.080	0.494	0.543	0.766	0.739	0.517
Fe	Plant	0.207	0.299	0.246	0.207	0.206	0.299	0.207
	Soil	**< 0.001**	0.674	0.296	0.759	0.666	0.785	0.920
Cu	Plant	0.271	**0.009**	**0.019**	**0.002**	**< 0.001**	**< 0.001**	0.095
	Soil	**< 0.001**	0.739	0.059	0.975	0.465	0.828	**0.022**
Na	Plant	**< 0.001**	**< 0.001**	0.907	**< 0.001**	0.124	0.260	0.266
	Soil	**< 0.001**	**0.007**	0.227	0.214	0.449	0.125	0.312
Zn	Plant	0.338	**0.008**	**0.015**	0.907	0.255	**0.005**	0.695
	Soil	0.708	0.229	0.314	0.563	0.970	0.720	0.897
Soil Characteristic	**Depth**	**Site**	**Spp**	**Trt**	**Site*Spp**	**Site*Trt**	**Spp*Trt**	**Site*Spp*Trt**
Bulk Density	0-0.2 m	0.713	0.651	**0.033**	**0.041**	0.872	0.853	0.451
	0.2-0.4 m	0.201	0.572	0.802	0.869	0.999	**0.046**	0.523
	0.4-0.6 m	0.369	**0.017**	0.483	0.287	0.222	0.485	0.677
	0.6-1.0 m	0.256	0.356	0.587	0.436	0.298	0.681	0.876

[*] : Plant is plant derived matter (sum of crop trees, midstory, understory, and forest floor) and Soil is total soil pool (0–1 m)

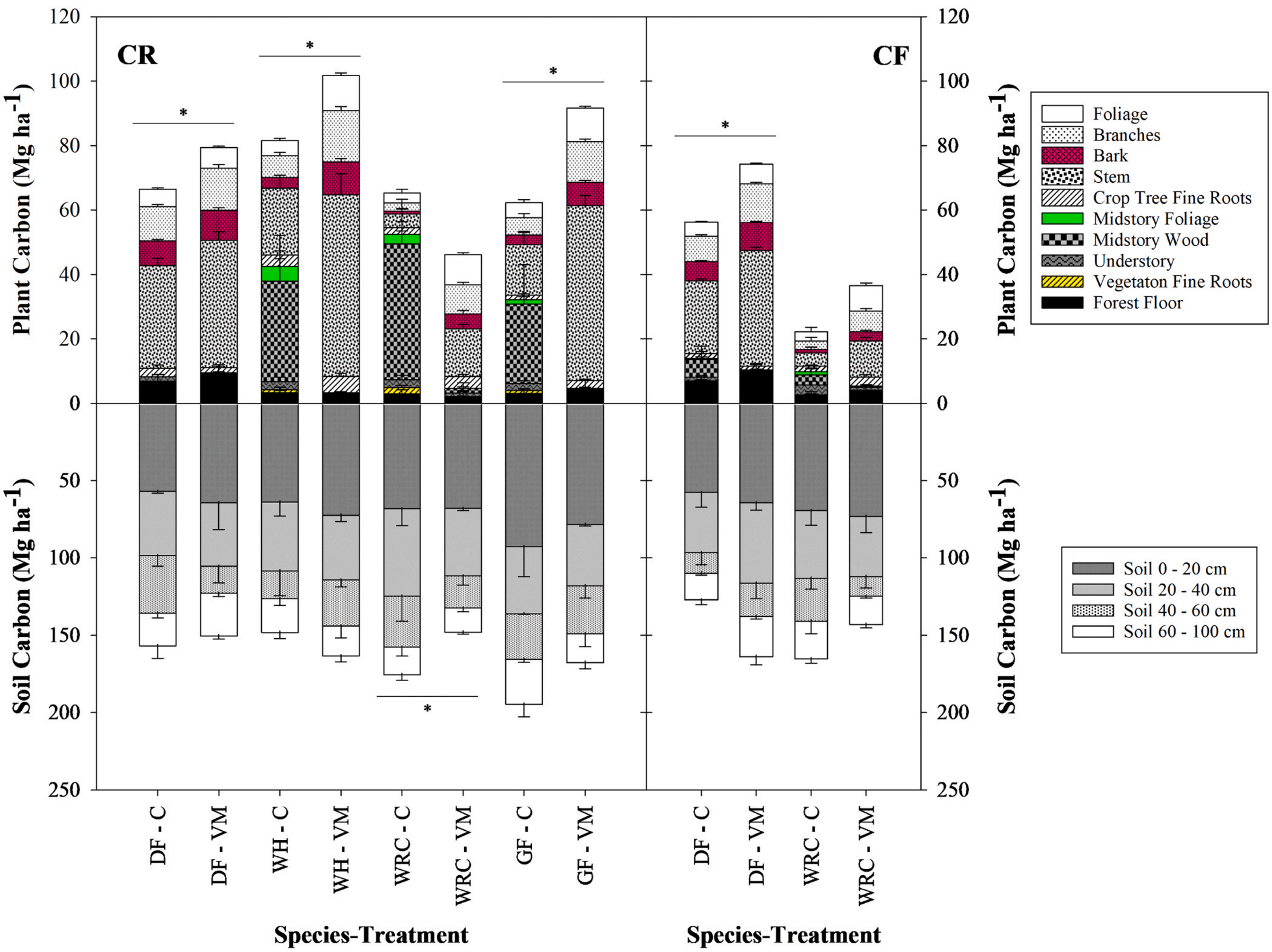

Fig. 2. Average carbon stocks (Mg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

3.4. Nitrogen budget

There was a significant species x treatment effect for N plant derived mass ($P = 0.013$; Fig. 3). At the CR site, the N mass was larger in the VM treatment for WH ($P = 0.032$), but no difference was detected for other species ($P > 0.1$). This was partly due to the robust understory and midstory in the WH and WRC Control plots, which contained 48% and 66% of total plant derived N mass, respectively. At the CF site, the plant derived N mass was larger in DF than in WRC. In Control plots, total crop tree biomass was significantly reduced, resulting in lower N mass stored in the crop tree tissue types. Total soil N mass did vary by site, but was affected by VM treatment for WH and WRC. For WH, soil N was larger in VM plots while for WRC, soil N was larger in Control plots ($P = 0.021$ and $P = 0.039$, respectively).

3.5. Phosphorous budget

There was a significant species x treatment effect ($P = 0.002$) for total plant derived P stocks such that only WH and GF displayed treatment effects (Fig. 4). WH and GF had more total plant derived P mass in VM plots. On the other hand, WRC had more plant derived P mass in Control plots at the CR site ($P = 0.046$). For these plots, there was less P in crop tree derived tissues and much more in the midstory and understory, which accounted for 44% of total plant P. This effect was opposite at the CF site due to a less abundant midstory. Total soil pools were not affected by VM treatments but were significantly lower at the CR site ($P = 0.853$ and $P = 0.002$, respectively).

3.6. Potassium budget

There was a significant species x treatment effect ($P = 0.019$) for plant derived K mass such that VM only increased K mass in GF (Fig. 5). Plant derived K mass did not differ between treatments for all other species at both sites ($P = 0.654$). Total soil K mass was larger at the CR site ($P < 0.001$) and was not affected by VM treatments.

3.7. Boron budget

There was a significant effect of VM treatments on plant derived mass of B across all species ($P = 0.002$, Fig. 6). WRC was the only exception, showing no differences between treated and untreated plots ($P > 0.2$). In WRC Control plots, the midstory and understory contributed 41% of total B mass at the CR site and 49% at the CF site. In GF and WH plots, the midstory and understory contributed 49% and 52% of total B mass, respectively. Soil pools varied significantly by site ($P < 0.01$), with the CR site having significantly reduced mass. Interestingly, DF foliar concentrations of B were significantly lower at the CR site and indicate marginal B bioavailability (Stone, 1990).

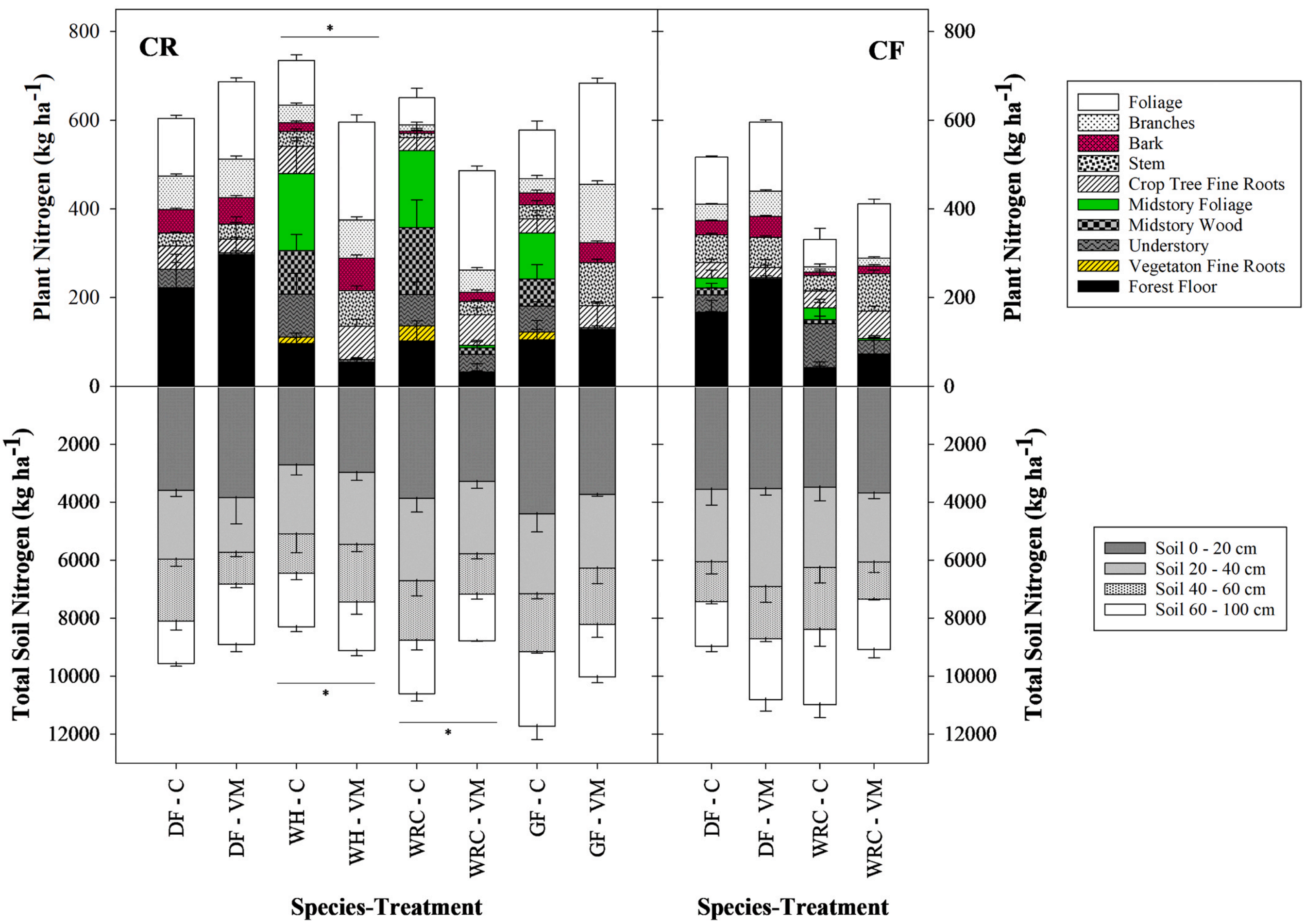

Fig. 3. Average nitrogen (N) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

3.8. Iron budget

Unlike previous nutrients, Fe was disproportionately stored in fine roots and forest floor, and very little was stored in aboveground, living plant tissue (Fig. 7). There were significant differences in Fe mass stored in many different crop tree derived tissues across sites and across treatments ($P < 0.05$; Appendix Tables A23 and A24), though there was no significant effect on total plant derived Fe mass. Since the concentrations in these crop tree pools do not vary by site or treatment, this difference was largely driven by differences in biomass. The total soil mass of Fe was greater at the CF site, but was unaffected by treatment.

3.9. Nutrients in harvestable pools

Distribution between tissues is important with regards to harvest removals. As typical harvest practices remove only the boles of trees, nutrients with high stemwood and stembark content are going to be removed in greater quantities. Table 5 shows the mass of each nutrient in crop tree stembark and stemwood, standardized by the mass of wood produced in Mg. At the CR site, WRC contained the most N, Ca, Mg, S, B, Fe and Zn in harvestable tissue when normalized to wood production while WH contained the most P, Cu, and Mn. DF had the lowest quantities of several nutrients, including N, Ca, Mg, B, Cu and Fe, contained in stemwood and stembark per unit wood produced. Differences between sites are less apparent than differences between species. At the CF site, both species contain notably more N in their stemwood and stembark, and DF contained more Mn. At the CR site, WRC contained more Ca and Fe in its stembark and stemwood. This shows that the different allocations to different tissues has a potentially meaningful effect on how nutrients would be removed in a harvest. At both sites, DF was the species that tended to contain less nutrient mass in harvestable tissues per unit of stemwood. However, it should be noted that this is only a snapshot of where nutrients are stored at 19 years and further study is needed to confirm whether or not these trends continue to a rotation age.

Appendix Table A41 reports the percentage of each nutrient stored in crop tree stem bark as a proportion of the mass stored in aboveground tissue. As VM increases the biomass allocation to crop trees, it is no surprise that for almost all of these nutrients, a greater percentage of the total plant derived nutrients are stored in crop tree stems in VM plots. Removals are generally lowest for WRC C plots since the crop trees represent a proportionately small amount of overall nutrient storage. Removals are generally highest for WH VM followed by GF VM, which also makes sense given that these were the conditions where crop tree biomass was greatest.

4. Discussion

4.1. Plant derived nutrient content

Nutrient content depends partially on the biomass of each component. VM treatments resulted in different stand characteristics. The

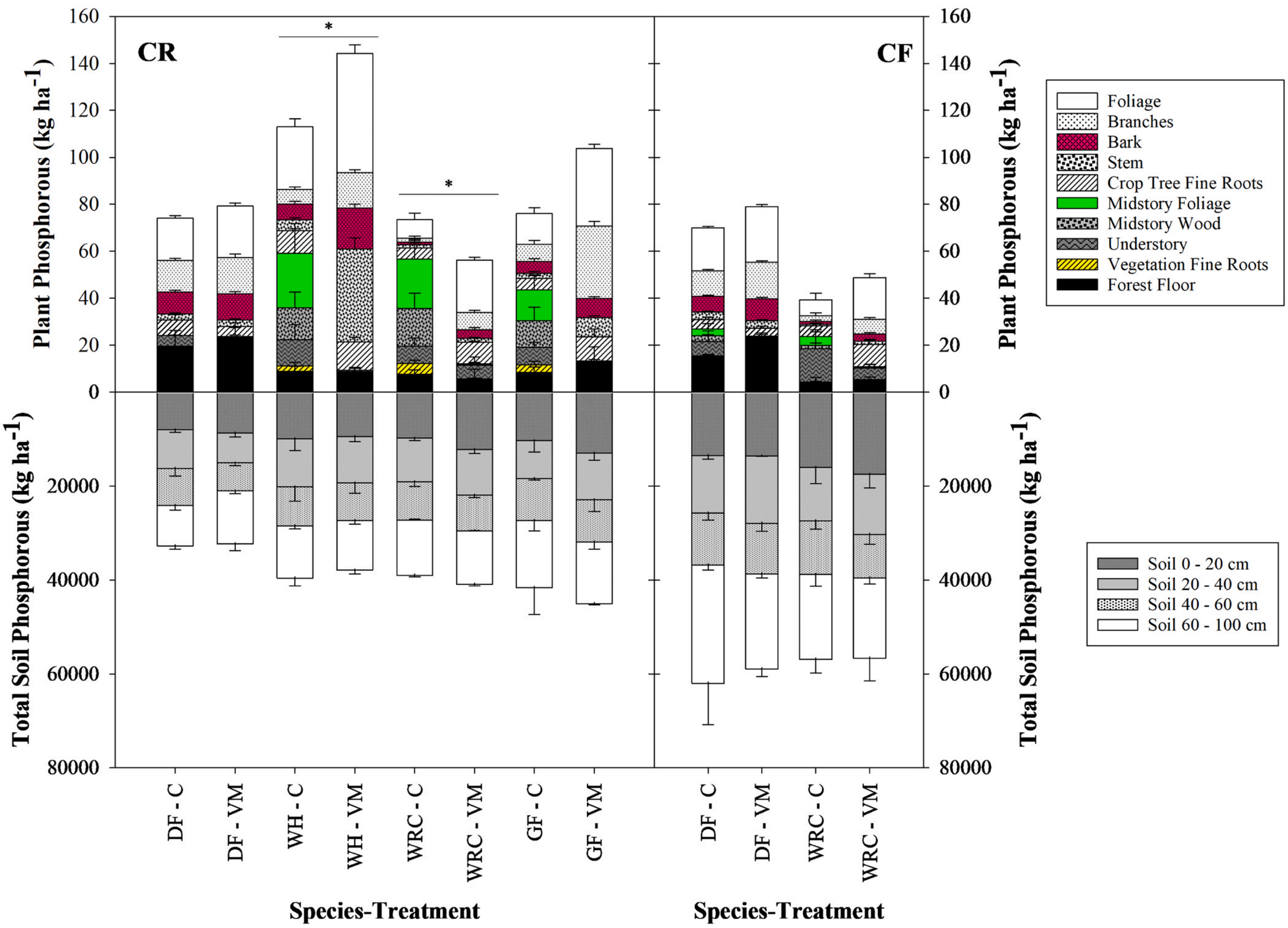

Fig. 4. Average phosphorous (P) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

TPHA, height, BA, and QMD were all greater under the VM treatment. This means that there were more crop trees in the VM plots and that they were larger in both height and diameter. The inverse is true with regards to midstory and understory development. VM plots had less midstory BA and tended to have lower understory mass. DF was a notable exception to this trend, as these stands tended not to develop a large midstory or understory biomass even in the Control plots. At this point in stand development, the midstory and understory biomasses were generally seen to decline (except for stands with low crop tree survival). This is because they are being overtopped by the crop trees and dying due to lack of light.

The age series presented by Turner and Long (1975) and Turner (1981) provides an excellent opportunity to compare datasets of macronutrient masses in Douglas-fir stands. In their analysis, the stands were grown under poor, severely N limited conditions in WA state. The TPHA (822–2756 trees ha^{-1}) and BA (32–57 m^2 ha^{-1}) of all stands in their age series were greater than the stands presented here, which averaged 703 trees ha^{-1} and 28 m^2 ha^{-1} at the CR site and 707 trees ha^{-1} and 23 m^2 ha^{-1} at the CF site. Lower stocking in our study may be due to thinning that occurred in DF stands at age 12. The foliar biomass in Douglas-fir stands in this analysis were greater than the maximum noted in Turner and Long (1975), which peaked around 40–50 years, and was similar to the foliar biomass reported for 20-year-old Douglas-fir in Littke et al. (2020). The biomass of stemwood, however, was less than that of the 22-year-old Turner stand. The weight of the bark and forest floor in this analysis was around that of the 30-year-old stand in Turner. Though the forest floor mass was higher, it was not as high as the 42-year-old stand (Turner and Long, 1975). With the exception of N, the macronutrient masses followed a similar trend. In general, foliage masses of P, K, and Ca were similar to that of the 42-year-old stand (note that with the exception of Ca, this is when foliage masses reached their maximum in the age series). The foliar nitrogen masses observed in our analysis were unsurprisingly higher than any of the stands in Turner (1981). Bark and stemwood masses of P, K, and Ca were similar to or less than the 22-year-old stand whereas N bark and stemwood mass was comparable to the 30-year-old stand. The forest floor mass of all nutrients was similar to the 42-year-old stand in Turner (1981). The most notable differences between these analyses were the significantly greater foliar biomass and relative mass of N caused by the N limitations of the WA stands. All other nutrient masses were comparable based on stands with similar biomass (Turner, 1981). Plant derived masses of Ca, Mg, and K are comparable to those of 50-year-old Douglas-fir stands in the WA Cascade foothills, though Mg and K masses were 47% and 36% greater, respectively, at the CR site (Homann et al., 1992).

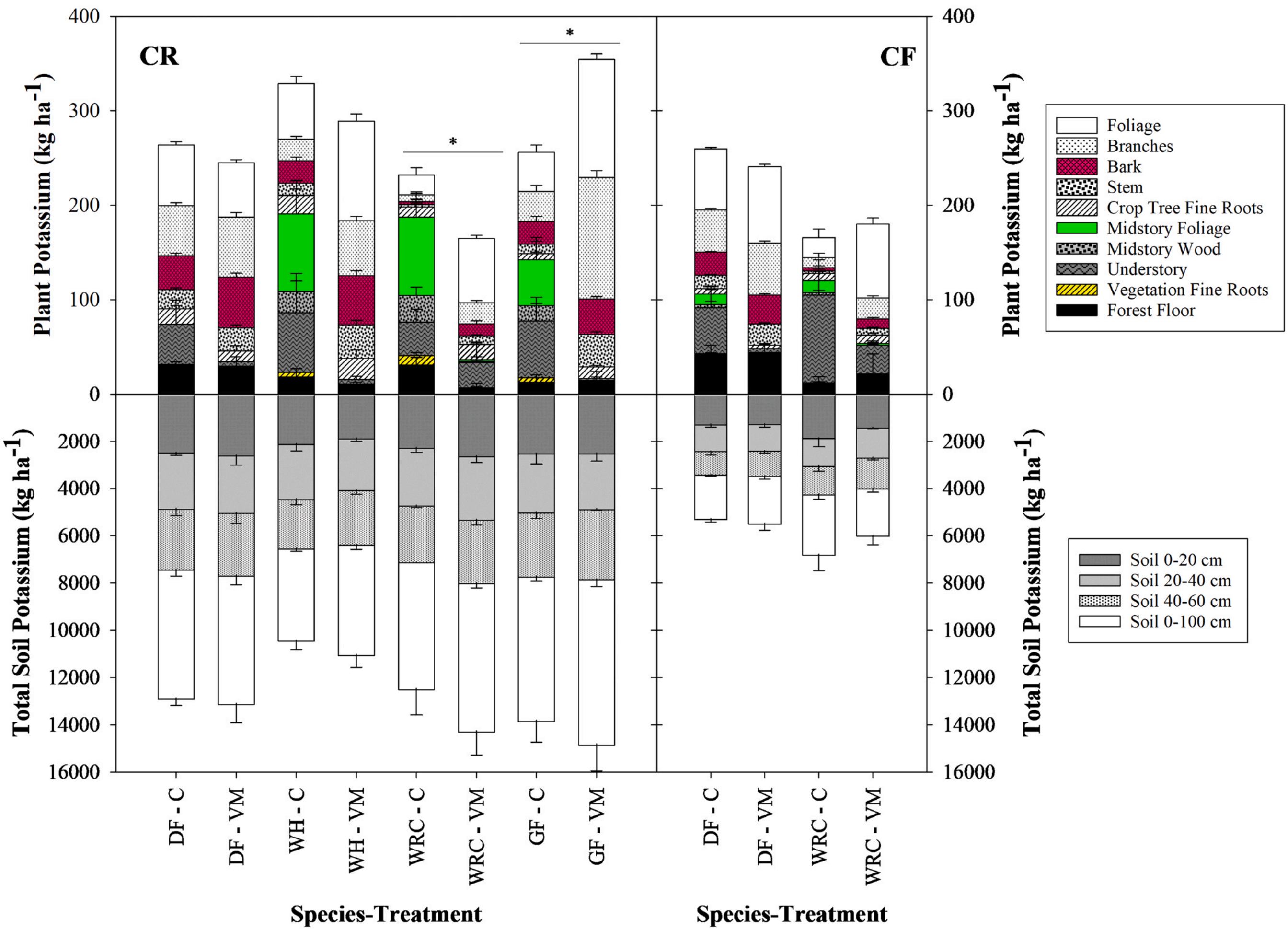

Fig. 5. Average potassium (K) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

4.1.1. Treatment effects

Calcium is the only element that displayed treatment differences without respect to site and species. All other nutrients with notable treatment effects varied either by site, species, or both. Mn, N, and K all displayed significant species x treatment effects. All other nutrients that were affected by treatment showed different responses to treatment based either on site (Cu, P), species (B, Cu, P, Zn), or site and species (C, Mg, S). Cu and N all displayed a marginally significant Site x Spp x Trt interaction ($P < 0.1$). This means that general trends about treatment effects can only be made for Ca. With very few exceptions, all crop tree tissues (foliage, branches, bark, and wood) had significantly greater masses with VM treatment for all species and nutrients. This is due to significant treatment differences in biomass for these tissues. Midstory tissues (midstory foliage and midstory wood) only showed significant treatment differences for WRC, with Control plots having higher nutrient mass. Understory nutrient masses generally only had significant treatment differences for DF, with Control plots having greater nutrient mass. Forest floor nutrient masses displayed very few treatment effects. The balance of these treatment effects on different tissues governed the responses of the total plant derived nutrient masses to treatment.

WRC plots responded very differently to the Control treatment based on site. Differences in stand development were the driving factors behind the numerous site x species x treatment effects for plant derived nutrient masses. At both sites, there was significant crop tree mortality in the absence of vegetation control, though it was more pronounced at the CF site. At the CR site, which experiences higher rainfall and shorter summer drought, there was significant recruitment of midstory species with an average basal area of 29.3 m^2 ha^{-1} in the Control plots (not including crop trees). At the CF site, there was little midstory development, only 2.7 m^2 ha^{-1} in the Control plots (Table 1). This may be due to differences in rainfall and summer drought, but may also be attributable to previous land use practices. The CF site is on reforested agricultural land and may not have as robust of a seed source or resprouting source for native hardwoods. At the CR site, Control plots developed more biomass due to the rapid accumulation of early seral hardwoods such as cherry and red alder, which were more productive than the shade tolerant WRC trees. At the CF site, the lack of midstory growth in Control plots led to a lower biomass accumulation than VM plots. Generally, aboveground nutrients followed the same trend, with Control plots having more plant derived nutrients at the CR site and VM plot having more at the CF site.

If the CR WRC data is excluded from the analysis, several nutrients display a constant treatment trend. C, Cu, P, and B, all tend to have greater plant derived masses in VM plots (with the exception of WRC plots at the CR site). This suggests that for these four elements, the direction of treatment effects depends largely on the development of midstory in the absence of VM.

Treatment effects of Ca were not altered by this difference in midstory development, and the WRC VM plots at the CR site had greater mass than did the Control plots. This is partially due to the fact that WRC

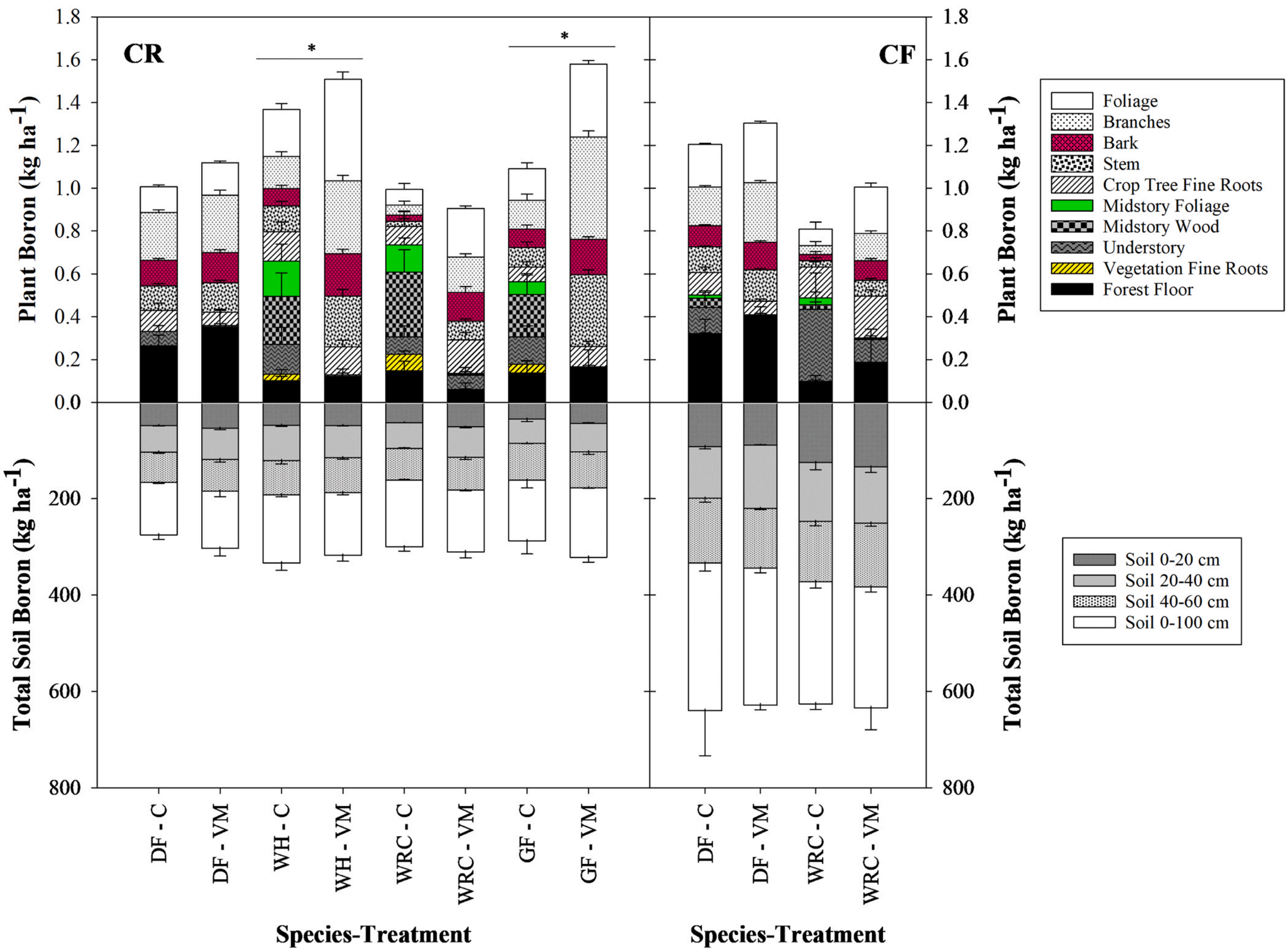

Fig. 6. Average boron (B) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

tends to sequester more Ca and generally has higher tissue concentrations than did the midstory species (Cannon et al., 2021). The VM plots had higher crop tree survival and growth, and averaged 3.5 times more aboveground crop tree biomass. This combined with the elevated tissue concentrations, overwhelmed the effect of the midstory.

4.1.2. Site effects

Site effects on plant derived nutrients were driven by differences in plant derived biomass between sites in some circumstances, but were also driven by differences in tissue concentrations between sites, such as with Mn. DF and WRC planted stands growing at the CR site tended to have greater plant derived biomass, which generally led to increased nutrient mass if there were no notable site-based concentration differences (with the exception of K, Ca, and Cu). B, Fe, and Mn had higher plant nutrient concentrations for various tissues of DF and WRC at the CF site. Due to this, B and Fe did not have significant Site effects, while Mn did. The concentration differences between sites were so large, that the CF site had higher plant derived Mn mass.

4.1.3. Species effects

Ca was the only nutrient that displayed species effects on plant derived nutrient content without any interactions. WRC and GF had greater plant derived Ca when compared to other species at the same site under the same treatment (see Appendix Figure A3). This is in agreement with studies in the inner mountain west that show GF to have more aboveground Ca content than DF (Parent and Coleman, 2016). The finding that WRC has high nutrient content compared to other species is unsurprising given that high Ca tissue concentrations are well documented and the species has been referred to as a ‘calciphile’ (Gessel et al., 1951; Krajina, 1969; Radwan and Harrington, 1986).

4.1.4. Nutrient distribution between tissues

Fe has a notably different nutrient budget than some of the others presented. The nutrient content is concentrated primarily in the fine roots and forest floor, whereas many other nutrients are preferentially allocated in leaves and other aboveground tissues. Iron is a unique nutrient in many ways. It is required in high amounts in meristems of actively growing tissue (Marschner and Marschner, 2012; Mengel, 1994). It tends to accumulate in root apoplasts and bind to hemicellulose, often in concentrations orders of magnitude higher than in the leaves (Marschner and Marschner, 2012; Mengel, 1994; Strasser et al., 1999). These stores may function to help prevent against Fe deficiency if plants are able to effectively mobilize this nutrient (Zhu et al., 2016). Notably, when Fe arrives at its destination in aboveground tissue, it is often permanently immobilized and is unable to be retranslocated from older to newer tissue. This means that the concentration of Fe in litter is likely to be higher than in living tissue. For a similar reason, it is less likely than more mobile nutrients to leach from litter. This may explain

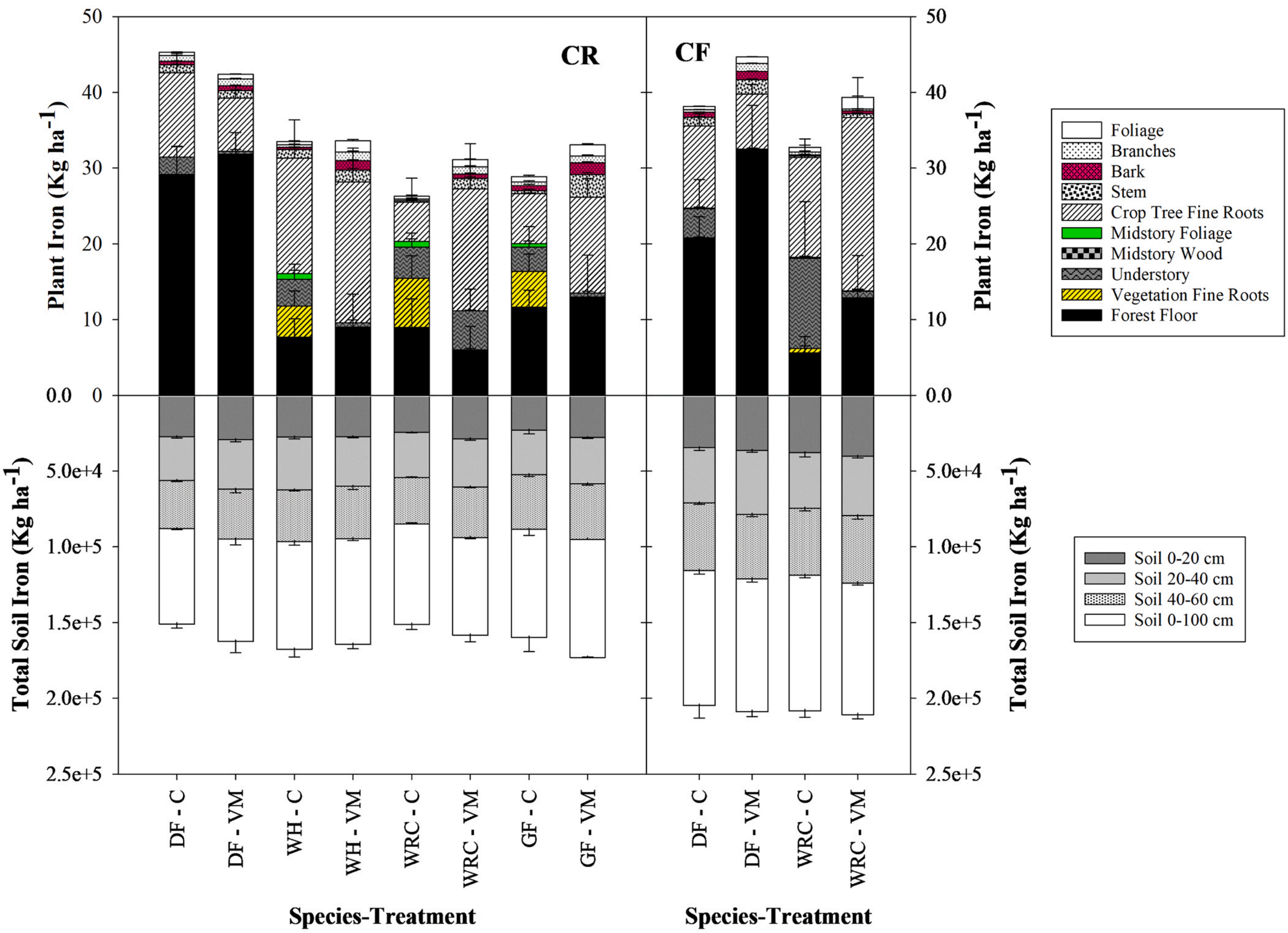

Fig. 7. Average iron (Fe) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM). Error bars represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

Table 5
Mass of nutrients stored in crop tree stembark and stemwood standardized by mass of stemwood produced for pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM), but the values presented here are for the VM treated plots only.

		Macronutrients (g nutrient/Mg wood)						Micronutrients (mg nutrient/Mg wood)					
Site	Species	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Na	Zn
CR	DF	23.6	3.5	19.8	18.4	3.9	9.5	0.71	0.31	4.13	7.32	5.21	20.05
	WH	27.2	5.2	15.6	31.4	4.1	9.0	0.77	0.47	5.01	31.04	3.40	16.96
	WRC	33.8	3.6	15.0	110.8	7.5	10.9	1.49	0.42	13.33	4.62	3.82	49.97
	GF	26.3	3.0	13.2	33.3	4.7	8.7	0.92	0.46	8.37	13.51	1.77	20.56
CF	DF	32.2	3.5	14.8	21.8	3.1	9.3	0.77	0.61	8.35	11.60	2.37	18.35
	WRC	90.1	3.9	15.4	64.7	5.6	10.0	1.45	0.43	7.74	4.66	1.38	47.85

why the forest floor is enriched with Fe compared to other tissues, though one study suggests that these inputs are too small and high forest floor concentrations are due to bioturbation of Fe from mineral soil into the litter layer (Li et al., 2017).

4.2. Soil nutrient content

Most studies of forest soil study, at the very least, the top 0.2 m of soil. However, forests are able to extract nutrients a much greater soil volume (Waltman et al., 2010; Jandl et al., 2014). Nutrient reserves are greatest near the surface for many nutrients, especially N, as this is where most of the biotic activity occurs in the soil and inputs from fine root turnover and aboveground litter tend to be highest. Nevertheless, few studies exist with sampling below the top 0.5 m of the soil. Trends with depth depend on the mineralogy at a site, and concentrations may increase with depth depending on soil properties and parent material chemistry (Callesen et al., 2016). In this study, we assessed soil up to 1 m depth.

Various methods can be employed to assess nutrient concentrations in forest soils. Because of the unique chemistry of each nutrient, there are diverse methods for quantifying various nutrient pools. These different pools are generally classified with respect to their availability to plants. P, for example, can be labile, moderately-labile, moderately-recalcitrant or stored in Ca complexes- though these 4 categories do not account for all the P in the soil (DeBruler et al., 2019). Certain studies only assess the labile or available pools, yet these pools are highly dynamic and can undergo changes throughout the year. Furthermore, some of these measures, such as concentrations of nitrite or nitrate, might inadequately reflect long-term availability and growth potential (Binkley and Hart, 1989; Powers, 1980). For the purpose of this study, the main concern is the total amount of nutrients in all pools and not the distribution of various soil fractions within the total pool. It is also worth noting that we did not perform soil nutrient sampling before the application of the VM treatments.

Total soil nutrient content for N and K in the top 0.6 m are similar to the Matlock, WA site in the LTSP study (DeBruler et al., 2019). Total soil P content, however, was around half of that site, much closer to the site near Mollala, OR. The soil contents of N, P, and K in the top 1 m of soil at the CR site agree well with data from another site in the Oregon Coast Range (Cromack et al., 1999). The largest difference was between Ca soil mass reported by Homann et al. (1992) and the Ca soil mass at the CR site. This is to be expected somewhat, as high N content in the Oregon Coast Range has been linked with Ca leaching (Compton et al., 2003; Homann et al., 1992; Hynicka et al., 2016) or to the fact that Homann et al. (1992) measured exchangeable cations instead of total as in this study.

There were relatively few effects on total soil nutrient content. Site effects on soil nutrient content show similar patterns to soil nutrient concentration, as soil bulk densities (and thus mass of soil layers) were similar between sites (Cannon et al., 2021). Mg was the only element that displayed marginally significant treatment effect across all species. Cu displayed a significant Site x Spp x Trt interaction due to the large difference between soil content in treatments for DF at the CF site. Mg and Na displayed significant differences between species. Mg generally had the lowest concentrations under WH. This may indicate that there is greater uptake or leaching of this nutrient under this species. It may also indicate that there is a blocking effect on total soil Mg concentrations or that the sampling regime was too simple to characterize soil heterogeneity (though it should be noted that block was included as a random factor in the mixed model). There was a significant Site x Spp x Trt effect for soil C in the 0.4 m – 0.6 m depth increment (Appendix Table A3), with C masses tending to be larger in Control plots. This is contrary to the findings at the Fall River LTSP site, which found higher deep soil carbon with VM (Knight et al., 2014). Notably, the reduced soil N concentration in VM plots of WRC at the CR site resulted in an overall decrease in total soil N mass. This may indicate the potential for VM applied to a slow growing species, such as WRC, to reduce ecosystem retention of N. As N is a common limiting nutrient in these forests, this has the potential to reduce growth of current and future stands (Mainwaring et al., 2014).

Generally, the lack of treatment differences in soil nutrient masses can be attributed to the fact that total soil nutrient reserves were one to three orders of magnitude greater than plant derived pools (with the exception of C and N). Any treatment differences in these nutrients (such as Cu or Mg) thus can likely not be explained entirely by differences in plant uptake, but may instead reflect soil heterogeneity, differences in leaching, or sampling/analysis error. The average standard error for Mg soil measurements for a given site, species, treatment, and depth was 570 kg ha^{-1} and the maximum plant derived mass was ~120 kg ha^{-1}.

5. Conclusions

A primary outcome of the contrasting vegetation management regimes applied in this study was not just creating trees of different growth rate and size, it created different ecosystems: an even aged monoculture (5 years of sustained vegetation control; VM regime) and an uneven aged multi-species stand with a more complex structure, including a conifer overstory, a broadleaf midstory, and an understory (No vegetation control after planting; Control). Analysis of long-term effects of those contrasting vegetation management regimes on whole-ecosystem biomass stock was previously reported by Flamenco et al. (2019).

Sustained vegetation management regimes tend to increase nutrient mass stored in crop tree tissues while having little effect on concentration, with bark and forest floor being the most notable exceptions. When other ecosystem components are included, the differences in plant derived nutrient mass between VM and Control plots become much less pronounced, and in some cases, Control plots even have higher nutrient masses, such as for WRC at the CR site. Nevertheless, nutrient mass in WRC Control plots was similar or lower than in VM plots of the other species tested at each site.

Ca was the only nutrient for which plant derived nutrient content varied only by treatment and not by site or species. For all other nutrients, treatment effects on plant derived nutrient content varied by site and species. Total Mg soil content displayed a marginally significant treatment effect, while Mg and sodium (Na) displayed differences between species. WRC at the CR site was the only site and species for which the Control plots had more plant derived nutrient content for almost all nutrients due to the large amount of midstory biomass in Control plots and comparatively small crop tree biomass in VM plots. If WRC at the CR site were to be excluded from analysis, carbon (C), copper (Cu), phosphorous (P), and boron (B) all tended to show higher plant derived nutrient content in VM plots. Of all tissue types, nutrient content of crop tree branches, bark, foliage, and stemwood had tended to be greater in VM plots as the biomass of all these tissues was significantly greater for all species.

Total soil nutrient reserves are 10 to 1000 times greater than the amount stored in plant tissue (excluding C, which is not taken up via plant roots), and therefore there were few treatment and species differences in soil content. Given that standard harvesting practices only remove stemwood and bark, the proportion of nutrient capital removed by harvesting is relatively low compared to total ecosystem nutrient storage, between 0.001% for Fe and 1.17% for Ca. WRC at the CR site, however, showed reduced total soil N mass under VM, indicating the potential for sustained vegetation control to reduce ecosystem N retention when this treatment is applied to a slow growing species, such as WRC. Nevertheless, it should be noted that this study quantified total soil nutrient pools and not exchangeable/plant accessible nutrient pools.

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Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Callan Cannon reports administrative support and travel were provided by Starker Forests. Callan Cannon reports administrative support and travel were provided by Cascade Timber Consulting.

Data availability

Data will be made available on request.

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Appendix A

Table A1-A14: Control: no post-planting vegetation control, VM: sustained vegetation control for first 5 years post-planting. Spp: Effect of species; Site: Effect of site; Trt: Effect of vegetation management treatment; Site x Spp: Interactive effect of species and site. Spp x Trt: Interactive effect of species and treatment. Site x Spp x Trt: Interactive effect of site, species and treatment. Species. P-value shown is in bold if the difference in concentration was significant at $\alpha = 0.05$.

Appendix Table A1
Results of ANOVA test for potassium (K) and sodium (Na) plant derived nutrient pools for 19 years old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). High concentration assumes stem tissue concentrations of 1.5 ppm Na and 0.03% K in all species. Low concentration assumes stem tissue concentrations of 0.05 ppm and 0.01% K in all species. Significant differences are highlighted in bold.

Assumption	Nutrient	Spp	Site	Trt	Site*Spp	Spp*Trt	Site*Trt	Site*Spp*Trt
High	K	**0.015**	0.343	0.088	0.491	**0.019**	0.123	0.120
	Na	**< 0.001**	**< 0.001**	0.425	**< 0.001**	0.260	0.124	0.266
Low	K	**0.015**	0.539	0.100	0.657	**0.032**	0.200	0.199
	Na	**< 0.001**	**< 0.001**	0.431	**< 0.001**	0.266	0.134	0.248

Appendix Table A2
Results of ANOVA test for nutrient pools of plant and soil derived boron (B) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

B - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		0.211	**0.004**	**0.002**	0.060	0.155	**0.005**	0.123
	Foliage	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.344	**< 0.001**	0.132
	Bark	**0.014**	**0.002**	**< 0.001**	0.662	0.190	**0.007**	0.085
	Branch	**0.030**	**< 0.001**	**< 0.001**	0.822	0.611	**< 0.001**	**0.014**
	Wood	0.834	**< 0.001**	**< 0.001**	0.235	0.393	**< 0.001**	0.196
	Plant Roots	0.209	0.223	0.577	0.294	0.745	0.407	0.856
	Mid Foliage	**0.038**	0.064	**0.002**	**0.006**	**0.028**	0.064	**0.004**
	Mid Wood	**0.015**	0.091	**0.001**	**0.003**	**0.016**	0.097	**0.003**
	Forest Floor	0.276	**0.001**	0.759	0.840	0.275	0.371	0.260
	Understory	0.063	0.679	**0.005**	0.189	0.143	0.378	0.392
	Veg Roots	**< 0.001**	**0.003**	**< 0.001**	**< 0.001**	**< 0.001**	**0.004**	**< 0.001**
Soil		**< 0.001**	0.701	0.436	0.814	0.779	0.728	0.803
	0.0-0.2 m	**< 0.001**	0.121	**0.043**	**0.010**	0.694	0.697	0.603
	0.2-0.4 m	**< 0.001**	0.129	0.227	0.801	0.932	0.386	0.148
	0.4-0.6 m	**< 0.001**	0.661	0.819	0.840	0.788	0.979	0.570
	0.6-1.0 m	**< 0.001**	0.594	0.855	0.256	0.823	0.574	0.715

Appendix Table A3
Results of ANOVA test for nutrient pools of plant and soil derived carbon (C) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

C - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**< 0.001**	**0.048**	**0.003**	**0.013**	**0.003**	**0.001**	**0.018**
	Foliage	0.073	**0.006**	**< 0.001**	0.851	0.713	**< 0.001**	0.156
	Bark	**0.003**	**< 0.001**	**< 0.001**	0.649	0.406	**0.001**	**0.017**
	Branch	**0.001**	**< 0.001**	**< 0.001**	0.437	0.633	**0.003**	**0.026**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**0.023**	0.568	**< 0.001**	**0.025**
	Plant Roots	0.105	**0.007**	0.160	0.849	0.878	0.186	0.376
	Mid Foliage	0.104	0.071	**0.004**	**0.026**	0.076	0.071	**0.019**
	Mid Wood	**0.009**	0.067	**0.001**	**0.002**	**0.008**	0.072	**0.001**
	Forest Floor	0.585	**0.010**	0.516	0.881	0.338	0.609	0.630
	Understory	0.835	0.339	**< 0.001**	0.593	0.515	0.636	0.405
	Veg Roots	**< 0.001**	**0.013**	**< 0.001**	**< 0.001**	**< 0.001**	**0.014**	**< 0.001**
Soil		0.469	0.403	0.332	0.975	0.198	0.501	0.305
	0.0-0.2 m	0.792	0.145	0.965	0.837	0.906	0.681	0.860
	0.2-0.4 m	0.781	0.866	0.443	0.455	0.176	0.905	0.716
	0.4-0.6 m	**0.011**	0.726	0.243	0.556	**0.046**	**0.028**	**0.016**
	0.6-1.0 m	0.797	0.549	0.570	0.355	0.881	0.486	0.578

Appendix Table A4
Results of ANOVA test for nutrient pools of plant and soil derived calcium (Ca) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Ca - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		0.215	**0.011**	**0.016**	0.132	0.222	0.245	0.930
	Foliage	0.679	**< 0.001**	**< 0.001**	0.776	0.418	**< 0.001**	0.158
	Bark	**0.008**	**0.040**	**< 0.001**	**0.007**	0.076	**< 0.001**	**0.002**
	Branch	**< 0.001**	**0.004**	**< 0.001**	0.586	**0.012**	**< 0.001**	**0.002**
	Wood	**< 0.001**	**0.001**	**< 0.001**	0.862	0.469	**< 0.001**	**< 0.001**
	Plant Roots	0.051	**0.047**	0.645	0.510	0.896	0.536	0.613
	Mid Foliage	**0.035**	0.072	**0.001**	**0.004**	**0.017**	0.074	**0.002**
	Mid Wood	**0.009**	0.075	**0.001**	**0.001**	**0.009**	0.081	**0.001**
	Forest Floor	0.226	**0.010**	0.650	0.971	**0.019**	0.592	0.171
	Understory	0.181	0.299	**0.005**	0.438	0.121	0.703	0.363
	Veg Roots	**< 0.001**	**0.011**	**< 0.001**	**< 0.001**	**< 0.001**	**0.011**	**< 0.001**
Soil		**< 0.001**	0.071	0.205	0.688	0.817	0.749	0.833
	0.0-0.2 m	**< 0.001**	0.148	0.984	0.825	0.647	0.981	0.271
	0.2-0.4 m	**< 0.001**	0.722	0.722	0.373	0.591	0.814	0.381
	0.4-0.6 m	**< 0.001**	0.518	**0.021**	0.431	0.649	0.786	0.851
	0.6-1.0 m	**< 0.001**	0.141	0.158	0.488	0.799	0.226	0.403

Appendix Table A5
Results of ANOVA test for nutrient pools of plant and soil derived copper (Cu) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Cu - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		0.271	**0.009**	**0.019**	**0.002**	**< 0.001**	**< 0.001**	0.095
	Foliage	0.948	**< 0.001**	**< 0.001**	0.809	0.884	**< 0.001**	0.319
	Bark	0.383	**< 0.001**	**< 0.001**	0.618	0.764	**0.039**	**0.039**
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	0.260	0.612	**< 0.001**	**< 0.001**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
	Plant Roots	0.263	0.224	0.214	0.082	0.609	0.120	0.308
	Mid Foliage	**0.028**	0.058	**0.001**	**0.006**	**0.022**	0.058	**0.004**
	Mid Wood	**0.005**	0.067	**0.001**	**0.001**	**0.005**	0.073	**0.001**
	Forest Floor	0.123	**0.033**	0.613	0.214	0.349	0.344	0.190
	Understory	0.653	0.706	**0.002**	0.177	0.381	0.465	0.131
	Veg Roots	**0.004**	**0.025**	**< 0.001**	**0.003**	**0.003**	**0.024**	**0.003**
Soil		**< 0.001**	0.739	0.059	0.975	0.465	0.828	**0.022**
	0.0-0.2 m	**< 0.001**	0.560	**0.037**	0.495	0.869	0.450	0.664
	0.2-0.4 m	**< 0.001**	0.521	0.705	0.313	0.262	0.581	0.270
	0.4-0.6 m	**< 0.001**	0.555	0.095	0.924	0.981	0.808	0.483
	0.6-1.0 m	**< 0.001**	0.416	0.116	0.940	0.593	0.841	**0.016**

Appendix Table A6
Results of ANOVA test for nutrient pools of plant and soil derived iron (Fe) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Fe - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		0.207	0.299	0.246	0.207	0.206	0.299	0.207
	Foliage	**0.004**	**< 0.001**	**< 0.001**	0.052	0.085	**< 0.001**	0.756
	Bark	**0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.974	**< 0.001**	**< 0.001**
	Branch	**< 0.001**	**0.007**	**< 0.001**	0.108	0.132	**< 0.001**	**< 0.001**
	Wood	0.262	**< 0.001**	**< 0.001**	**< 0.001**	0.561	**< 0.001**	**< 0.001**
	Plant Roots	0.086	0.082	0.106	0.083	0.935	0.187	0.831
	Mid Foliage	**0.023**	0.082	**0.001**	**0.002**	**0.018**	0.085	**0.002**
	Mid Wood	**0.006**	0.056	**0.001**	**0.001**	**0.004**	0.061	**0.001**
	Forest Floor	0.669	**< 0.001**	0.808	0.261	0.067	0.847	0.902
	Understory	0.568	0.225	0.155	0.791	0.110	0.571	0.231
	Veg Roots	**0.026**	0.130	**0.002**	**0.021**	**0.023**	0.126	**0.018**
Soil		**< 0.001**	0.674	0.296	0.759	0.666	0.785	0.920
	0.0-0.2 m	**< 0.001**	0.524	**0.037**	0.093	0.748	0.409	0.767
	0.2-0.4 m	**< 0.001**	0.181	0.358	0.616	0.687	0.373	0.785
	0.4-0.6 m	**< 0.001**	0.545	0.436	0.731	0.416	0.946	0.892
	0.6-1.0 m	**< 0.001**	0.434	0.563	0.959	0.661	0.776	0.738

Appendix Table A7
Results of ANOVA test for nutrient pools of plant and soil derived potassium (K) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

K - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		0.343	**0.015**	0.654	0.491	0.123	**0.019**	0.120
	Foliage	**0.020**	**< 0.001**	**< 0.001**	0.306	**0.018**	**< 0.001**	0.303
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.006**	**0.025**	0.109
	Branch	0.068	**< 0.001**	**< 0.001**	**0.011**	0.580	**< 0.001**	0.642
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**0.013**	0.581	**< 0.001**	**0.037**
	Plant Roots	**0.009**	0.205	0.501	0.353	0.919	0.558	0.382
	Mid Foliage	**0.022**	0.067	**0.001**	**0.004**	**0.020**	0.069	**0.003**
	Mid Wood	**0.010**	0.069	**0.001**	**0.002**	**0.009**	0.074	**0.001**
	Forest Floor	0.369	**0.006**	**0.032**	0.212	0.129	0.092	0.209
	Understory	0.196	0.951	**0.008**	0.274	0.232	0.580	0.347
	Veg Roots	**< 0.001**	**0.030**	**< 0.001**	**< 0.001**	**< 0.001**	**0.030**	**< 0.001**
Soil		**< 0.001**	0.052	0.323	0.726	0.261	0.937	0.272
	0.0-0.2 m	**< 0.001**	0.179	0.766	0.198	0.141	0.779	0.280
	0.2-0.4 m	**< 0.001**	0.722	0.999	0.777	0.761	0.886	0.903
	0.4-0.6 m	**< 0.001**	0.099	0.244	0.426	0.669	0.980	0.692
	0.6-1.0 m	**< 0.001**	**0.043**	0.248	0.968	0.380	0.898	0.273

Appendix Table A8
Results of ANOVA test for nutrient pools of plant and soil derived magnesium (Mg) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Mg - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**0.001**	0.196	**0.001**	0.080	**0.004**	**0.021**	**0.020**
	Foliage	**< 0.001**	**0.001**	**< 0.001**	0.094	0.955	**0.001**	**0.009**
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	**0.004**	0.792	**0.002**	**0.002**
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	**0.003**	0.778	**< 0.001**	**< 0.001**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	0.057	**0.011**	**< 0.001**	**0.007**
	Plant Roots	**0.047**	**0.033**	0.298	0.795	0.803	0.333	0.354
	Mid Foliage	**0.023**	0.081	**0.001**	**0.004**	**0.021**	0.085	**0.003**
	Mid Wood	**0.002**	**0.049**	**0.001**	**< 0.001**	**0.002**	0.053	**< 0.001**
	Forest Floor	0.427	**0.003**	0.248	0.871	0.178	0.304	0.129
	Understory	0.469	0.522	**0.005**	0.394	0.290	0.271	0.287
	Veg Roots	**< 0.001**	**0.014**	**< 0.001**	**< 0.001**	**< 0.001**	**0.014**	**< 0.001**
Soil		**< 0.001**	**0.018**	0.051	0.254	0.369	0.537	0.461
	0.0-0.2 m	**< 0.001**	**0.033**	**0.049**	0.167	0.309	0.468	0.118
	0.2-0.4 m	**< 0.001**	0.371	0.288	0.659	0.500	0.240	0.275
	0.4-0.6 m	**< 0.001**	**0.041**	0.151	0.296	0.325	0.777	0.648
	0.6-1.0 m	**< 0.001**	**0.008**	0.071	0.210	0.472	0.507	0.725

Appendix Table A9
Results of ANOVA test for nutrient pools of plant and soil derived manganese (Mn) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Mn - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**< 0.001**	**< 0.001**	**< 0.001**	0.709	0.288	**0.001**	0.912
	Foliage	**0.047**	**< 0.001**	**< 0.001**	**0.025**	0.491	**< 0.001**	0.348
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.144	**< 0.001**	0.446
	Branch	**0.002**	**< 0.001**	**< 0.001**	0.128	0.093	**< 0.001**	**< 0.001**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.049**	**< 0.001**	**0.008**
	Plant Roots	**< 0.001**	**0.045**	**0.031**	**0.016**	0.816	0.116	0.292
	Mid Foliage	0.385	0.091	**0.018**	0.213	0.190	0.089	0.095
	Mid Wood	**0.015**	0.074	**0.004**	**0.004**	**0.010**	0.075	**0.002**
	Forest Floor	**0.009**	**0.008**	0.080	0.252	0.245	0.548	0.938
	Understory	0.395	0.964	**0.029**	0.109	0.379	0.598	0.111
	Veg Roots	**0.020**	0.089	**0.001**	**0.012**	**0.015**	0.086	**0.009**
Soil		**< 0.001**	0.080	0.494	0.543	0.766	0.739	0.517
	0.0-0.2 m	**< 0.001**	0.212	**0.006**	0.128	0.652	**0.034**	0.920
	0.2-0.4 m	**< 0.001**	**0.024**	0.847	0.927	0.282	0.992	0.573
	0.4-0.6 m	**< 0.001**	0.103	0.731	0.349	0.774	0.604	0.109
	0.6-1.0 m	**0.003**	0.498	0.937	0.680	0.471	0.469	0.934

Appendix Table A10
Results of ANOVA test for nutrient pools of plant and soil derived nitrogen (N) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

N - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**0.012**	0.732	0.341	0.282	0.075	**0.013**	0.067
	Foliage	**< 0.001**	0.234	**< 0.001**	0.080	**0.005**	**0.001**	**0.003**
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.463	**< 0.001**	**0.018**
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	**0.003**	**0.034**	**< 0.001**	**0.001**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	0.491	**0.050**	**< 0.001**	**0.037**
	Plant Roots	0.369	0.156	0.165	0.323	0.760	0.111	0.205
	Mid Foliage	**0.029**	0.072	**0.001**	**0.006**	**0.027**	0.075	**0.005**
	Mid Wood	**0.037**	0.070	**0.001**	**0.015**	**0.015**	**0.045**	**0.004**
	Forest Floor	0.341	**0.001**	0.918	0.507	0.394	0.414	0.400
	Understory	0.785	0.310	**0.001**	0.678	0.522	0.422	0.482
	Veg Roots	**0.001**	**0.008**	**< 0.001**	**0.001**	**0.001**	**0.008**	**0.001**
Soil		0.445	0.087	0.161	0.802	0.316	0.341	0.287
	0.0-0.2 m	0.794	0.094	0.586	0.787	0.698	0.640	0.421
	0.2-0.4 m	0.325	0.551	0.400	0.225	0.124	0.860	0.100
	0.4-0.6 m	0.900	0.748	0.205	0.988	0.136	0.061	0.060
	0.6-1.0 m	0.350	0.422	0.437	0.462	0.284	0.063	0.397

Appendix Table A11
Results of ANOVA test for nutrient pools of plant and soil derived sodium (Na) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Na - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**< 0.001**	**< 0.001**	0.907	**< 0.001**	0.124	0.260	0.266
	Foliage	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.004**	**0.011**
	Bark	**< 0.001**	**< 0.001**	0.680	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.988	**< 0.001**	**< 0.001**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**0.013**	0.581	**< 0.001**	**0.037**
	Plant Roots	0.075	0.371	0.152	0.577	0.767	0.099	0.125
	Mid Foliage	0.098	0.071	**0.005**	**0.033**	0.103	0.069	**0.034**
	Mid Wood	0.268	0.085	**0.009**	0.122	0.271	0.084	0.123
	Forest Floor	**0.008**	**< 0.001**	0.962	0.136	0.108	0.490	0.487
	Understory	0.960	0.524	**0.003**	0.627	0.214	0.198	0.134
	Veg Roots	**0.033**	0.080	**0.005**	**0.031**	**0.031**	0.078	**0.029**
Soil		**< 0.001**	**0.007**	0.227	0.214	0.449	0.125	0.312
	0.0-0.2 m	**< 0.001**	**0.014**	**0.022**	**< 0.001**	0.479	0.650	0.956
	0.2-0.4 m	0.449	0.054	0.774	0.437	0.221	0.433	0.551
	0.4-0.6 m	**< 0.001**	**< 0.001**	0.305	**0.002**	0.215	0.080	0.073
	0.6-1.0 m	**< 0.001**	**0.033**	0.702	0.817	0.164	0.104	0.511

Appendix Table A12
Results of ANOVA test for nutrient pools of plant and soil derived phosphorous (P) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

P - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**0.009**	**0.002**	**0.045**	**0.027**	**0.036**	**0.002**	0.105
	Foliage	**< 0.001**	**< 0.001**	**< 0.001**	0.061	0.654	**0.001**	0.217
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	**0.003**	0.951	**< 0.001**	0.171
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	0.241	0.754	**< 0.001**	**0.022**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**0.005**	0.067	**< 0.001**	0.573
	Plant Roots	0.463	0.113	0.105	0.417	0.550	0.221	0.741
	Mid Foliage	**0.029**	0.082	**0.001**	**0.003**	**0.025**	0.084	**0.003**
	Mid Wood	**0.034**	0.125	**0.002**	**0.007**	**0.037**	0.131	**0.007**
	Forest Floor	0.292	**0.001**	0.512	0.982	0.254	0.719	0.872
	Understory	0.335	0.413	**0.007**	0.582	0.250	0.399	0.441
	Veg Roots	**< 0.001**	**0.021**	**< 0.001**	**< 0.001**	**< 0.001**	**0.021**	**< 0.001**
Soil		**0.002**	0.256	0.835	0.340	0.735	0.964	0.975
	0.0-0.2 m	**0.005**	0.215	0.258	0.856	0.630	0.712	0.905
	0.2-0.4 m	**0.006**	0.452	0.991	0.200	0.210	0.802	0.450
	0.4-0.6 m	**0.010**	0.354	0.400	0.472	0.948	0.811	0.351
	0.6-1.0 m	**0.002**	0.437	0.902	0.217	0.441	0.729	0.521

Appendix Table A13

Results of ANOVA test for nutrient pools of plant and soil derived Sulfur (S) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

S - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		**0.001**	0.703	**0.013**	**0.024**	**0.005**	0.069	**0.003**
	Foliage	**0.009**	**< 0.001**	**< 0.001**	**0.002**	0.500	0.328	0.189
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	**0.030**	0.494	**< 0.001**	**< 0.001**
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	**0.006**	0.624	**< 0.001**	**0.002**
	Wood	**< 0.001**	**< 0.001**	**< 0.001**	**0.008**	0.740	**< 0.001**	**0.027**
	Plant Roots	0.457	0.084	0.072	0.386	0.770	0.069	0.276
	Mid Foliage	0.102	0.082	**0.007**	**0.027**	0.079	0.082	**0.020**
	Mid Wood	**0.024**	0.131	**0.002**	**0.004**	**0.026**	0.138	**0.005**
	Forest Floor	0.460	**0.004**	0.622	0.676	0.392	0.605	0.723
	Understory	0.635	0.542	**0.004**	0.886	0.505	0.441	0.233
	Veg Roots	**0.001**	**0.027**	**< 0.001**	**0.001**	**0.001**	**0.027**	**0.001**

Appendix Table A14

Results of ANOVA test for nutrient pools of plant and soil derived zinc (Zn) masses for 19-year-old Douglas-fir, western hemlock, western redcedar and grand fir (Spp) growing under contrasting treatments of vegetation management (Trt) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon (Site). Significant differences are highlighted in bold.

Zn - Pool		Site	Spp	Trt	Site*Spp	Site*Trt	Spp*Trt	Site*Spp*Trt
Plant		0.338	**0.008**	**0.015**	0.907	0.255	**0.005**	0.695
	Foliage	0.409	**< 0.001**	**< 0.001**	0.468	0.921	**< 0.001**	0.287
	Bark	**< 0.001**	**< 0.001**	**< 0.001**	0.460	0.181	0.217	0.206
	Branch	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.249	**< 0.001**	**0.030**
	Wood	**0.001**	**< 0.001**	**< 0.001**	**0.003**	**< 0.001**	**< 0.001**	**< 0.001**
	Plant Roots	0.247	0.166	0.109	0.154	0.385	0.358	0.393
	Mid Foliage	**0.038**	0.065	**0.002**	**0.007**	**0.022**	0.062	**0.004**
	Mid Wood	**0.014**	0.075	**0.001**	**0.003**	**0.010**	0.076	**0.002**
	Forest Floor	0.244	**0.039**	0.645	0.581	0.370	0.635	0.886
	Understory	0.453	0.699	**0.011**	0.210	0.639	0.467	0.366
	Veg Roots	**0.005**	**0.009**	**< 0.001**	**0.005**	**0.006**	**0.010**	**0.005**
Soil		0.708	0.229	0.314	0.563	0.970	0.720	0.897
	0.0-0.2 m	0.184	0.653	**0.014**	0.181	0.700	0.307	0.996
	0.2-0.4 m	0.787	0.198	0.408	0.604	0.251	0.762	0.836
	0.4-0.6 m	0.578	0.131	0.923	0.630	0.554	0.922	0.838
	0.6-1.0 m	0.744	0.217	0.213	0.541	0.606	0.420	0.794

Appendix Table A15

Mass (kg ha^{-1}) of boron (B) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	1.009	0.022	1.121	0.079	1.206	0.077	1.306	0.055	**0.043**	0.051	0.885
	Foliage	0.120	0.005	0.150	0.006	0.199	0.003	0.278	0.006	**< 0.001**	**< 0.001**	**0.001**
	Branches	0.223	0.009	0.268	0.017	0.179	0.004	0.277	0.007	**< 0.001**	0.130	**0.030**
	Bark	0.117	0.005	0.141	0.008	0.099	0.002	0.129	0.003	**< 0.001**	**0.012**	0.561
	Wood	0.114	0.006	0.138	0.007	0.119	0.002	0.146	0.003	**< 0.001**	0.231	0.690
	Tree Roots	0.098	0.026	0.062	0.003	0.106	0.020	0.064	0.006	**0.037**	0.815	0.863
	Mid Foliage	0.000	0.000	0.000	0.000	0.015	0.008	0.000	0.000	0.107	0.107	0.107
	Mid Wood	0.000	0.000	0.000	0.000	0.043	0.027	0.000	0.000	0.170	0.170	0.170
	Understory	0.067	0.020	0.007	0.004	0.122	0.046	0.005	0.003	**0.012**	0.335	0.292
	Forest Floor	0.269	0.039	0.355	0.070	0.323	0.056	0.406	0.035	0.146	0.354	0.977
	Veg Roots	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	**0.002**	**0.002**	**0.002**
	Total Soil	272.49	16.36	300.12	39.41	636.64	106.49	624.93	20.72	0.894	**< 0.001**	0.742
	0.0-0.2 m	45.82	2.79	51.27	4.67	89.30	6.43	86.67	1.14	0.745	**< 0.001**	0.361
	0.2-0.4 m	55.19	3.61	64.90	6.78	107.10	9.32	131.17	4.33	**0.022**	**< 0.001**	0.285
	0.4-0.6 m	62.88	3.59	65.70	11.87	134.56	16.87	123.65	10.70	0.737	**< 0.001**	**< 0.001**
	0.6-1.0 m	108.60	10.75	118.25	16.59	305.68	83.88	283.43	11.49	0.887	**0.001**	0.720
WRC	Total Plant	0.997	0.054	0.908	0.056	0.812	0.112	1.007	0.055	0.524	0.607	0.109
	Foliage	0.074	0.025	0.226	0.009	0.076	0.025	0.216	0.014	**0.001**	0.862	0.770
	Branches	0.045	0.017	0.165	0.012	0.042	0.014	0.126	0.008	**< 0.001**	0.132	0.199
	Bark	0.029	0.013	0.133	0.025	0.030	0.009	0.091	0.006	**< 0.001**	0.147	0.143
	Wood	0.024	0.009	0.087	0.006	0.029	0.009	0.073	0.005	**< 0.001**	0.568	0.227

(*continued on next page*)

Appendix Table A15 (*continued*)

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
	Tree Roots	0.087	0.069	0.157	0.031	0.144	0.018	0.195	0.021	0.136	0.249	0.800
	Mid Foliage	0.125	0.030	0.003	0.003	0.034	0.021	0.005	0.005	**0.002**	**0.031**	**0.025**
	Mid Wood	0.303	0.100	0.006	0.006	0.021	0.010	0.002	0.002	**0.013**	**0.021**	**0.021**
	Understory	0.082	0.047	0.067	0.033	0.335	0.145	0.108	0.038	0.216	0.140	0.275
	Forest Floor	0.151	0.041	0.063	0.028	0.096	0.025	0.191	0.095	0.958	0.568	0.172
	Veg Roots	0.077	0.012	0.001	0.001	0.006	0.002	0.000	0.000	**0.001**	**0.001**	**0.001**
	Total Soil	297.35	12.21	307.66	29.36	622.89	48.17	630.90	65.07	0.693	**0.005**	0.960
	0.0-0.2 m	40.40	1.71	48.69	4.05	122.41	15.08	131.82	12.09	0.301	**0.002**	0.945
	0.2-0.4 m	52.83	0.91	62.78	7.27	122.55	10.10	116.40	7.41	0.796	**0.001**	0.300
	0.4-0.6 m	65.71	0.86	68.38	3.42	124.67	13.75	132.30	11.65	0.433	**0.007**	0.699
	0.6-1.0 m	138.41	11.45	127.81	15.52	253.26	12.60	250.38	42.32	0.770	**0.014**	0.866

Appendix Table A16

Mass (kg ha^{-1}) of boron (B) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	1.369	0.089	1.510	0.101	**0.036**
	Foliage	0.218	0.023	0.473	0.029	**< 0.001**
	Branches	0.149	0.016	0.340	0.021	**< 0.001**
	Bark	0.082	0.010	0.197	0.015	**< 0.001**
	Wood	0.119	0.016	0.236	0.023	**0.006**
	Tree Roots	0.137	0.035	0.130	0.023	0.879
	Mid Foliage	0.166	0.065	0.000	0.000	0.085
	Mid Wood	0.224	0.092	0.000	0.000	0.092
	Understory	0.137	0.065	0.008	0.003	0.093
	Forest Floor	0.105	0.015	0.126	0.026	0.458
	Veg Roots	0.032	0.013	0.000	0.000	0.098
	Total Soil	330.72	19.86	315.08	21.62	0.535
	0.0-0.2 m	45.23	4.36	46.37	2.37	0.766
	0.2-0.4 m	73.15	7.95	65.91	5.02	0.471
	0.4-0.6 m	71.30	5.43	72.71	5.69	0.841
	0.6-1.0 m	141.04	15.91	130.10	12.92	0.510
GF	Total Plant	1.094	0.089	1.581	0.145	0.052
	Foliage	0.147	0.025	0.339	0.016	**0.019**
	Branches	0.135	0.026	0.477	0.026	**0.008**
	Bark	0.085	0.017	0.165	0.009	**0.041**
	Wood	0.090	0.023	0.336	0.018	**0.005**
	Tree Roots	0.070	0.021	0.093	0.020	0.462
	Mid Foliage	0.060	0.029	0.000	0.000	0.174
	Mid Wood	0.197	0.096	0.000	0.000	0.176
	Understory	0.127	0.048	0.006	0.002	0.127
	Forest Floor	0.142	0.054	0.165	0.081	0.823
	Veg Roots	0.040	0.011	0.000	0.000	0.071
	Total Soil	284.95	56.53	318.92	8.03	0.584
	0.0-0.2 m	32.59	7.32	41.37	1.13	0.302
	0.2-0.4 m	49.85	3.40	59.05	7.22	0.313
	0.4-0.6 m	76.81	18.21	74.35	3.64	0.890
	0.6-1.0 m	125.70	29.78	144.16	12.87	0.541

Appendix Table A17

Mass (kg ha^{-1}) of carbon (C) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	66621	2613	79526	3816	56444	3092	74402	2188	**0.001**	0.060	0.374
	Foliage	5428	237	6374	252	4304	67	6101	142	**< 0.001**	**0.003**	**0.045**
	Branches	10653	440	13109	850	7890	167	12005	322	**< 0.001**	**0.003**	0.131
	Bark	7553	321	9259	537	6030	98	8693	206	**< 0.001**	**0.009**	0.176

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Appendix Table A17 (*continued*)

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	**Tissue**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**Trt**	**Site**	**Site*Trt**
	Wood	31792	1699	39429	2114	22507	310	35810	763	**< 0.001**	**0.001**	0.069
	Tree Roots	2691	625	1567	199	1465	343	1162	223	0.057	0.123	0.225
	Mid Foliage	0	0	0	0	320	191	0	0	0.145	0.145	0.145
	Mid Wood	0	0	0	0	5560	3344	0	0	0.147	0.147	0.147
	Understory	1305	365	128	67	1136	264	81	52	**0.002**	0.674	0.784
	Forest Floor	7199	1548	9660	2065	7213	904	10549	1578	0.079	0.807	0.760
	Veg Roots	0	0	0	0	18	5	0	0	**0.010**	**0.010**	**0.010**
	Total Soil	155932	7429	149564	10599	126354	17133	162872	17212	0.223	0.629	0.102
	0.0-0.2 m	56116	1728	63608	15627	56888	8887	63608	4661	0.461	0.968	0.968
	0.2-0.4 m	41638	6549	41027	10047	38917	7525	51858	9534	0.247	0.727	0.209
	0.4-0.6 m	37140	3396	17436	2534	13235	1848	21433	2222	**0.045**	**0.002**	**0.000**
	0.6-1.0 m	21038	7883	27493	2420	17314	3356	25973	5548	0.086	0.698	0.774
WRC	Total Plant	65447	8301	46384	2401	22479	5585	36791	2771	0.627	**0.006**	**0.015**
	Foliage	3046	1033	9457	396	2904	965	7904	523	**0.001**	0.353	0.399
	Branches	2543	949	8929	650	2553	827	6434	430	**< 0.001**	0.120	0.118
	Bark	916	415	4547	856	1070	309	2812	184	**< 0.001**	0.110	0.063
	Wood	4238	1570	14806	1036	4171	1355	11277	754	**< 0.001**	0.168	0.183
	Tree Roots	2039	1597	3645	423	1677	74	2700	419	0.104	0.396	0.701
	Mid Foliage	2946	786	92	92	964	601	168	168	**0.004**	0.084	0.065
	Mid Wood	42093	12511	1449	1449	3110	1576	214	214	**0.008**	**0.016**	**0.014**
	Understory	2401	1111	1161	518	3138	666	914	174	**0.025**	0.716	0.470
	Forest Floor	3311	865	2285	1366	2806	692	4369	1240	0.791	0.534	0.236
	Veg Roots	1914	346	14	14	84	32	0	0	**0.001**	**0.002**	**0.002**
	Total Soil	174523	7798	147100	10103	164489	15059	142188	13666	0.088	0.583	0.850
	0.0-0.2 m	67383	11774	67189	2110	68561	8887	72319	9796	0.852	0.741	0.836
	0.2-0.4 m	56523	16962	43663	6683	43741	6930	38878	7246	0.185	0.510	0.519
	0.4-0.6 m	32754	6841	20673	3332	27832	7693	12742	1806	**0.037**	0.282	0.796
	0.6-1.0 m	17864	4676	15574	2181	24354	3124	18248	2760	0.229	0.192	0.573

Appendix Table A18
Mass (kg ha^{-1}) of carbon (C) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

02		Control		VM		P-value
Species	**Tissue**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**Trt**
WH	Total Plant	81671	11754	101810	7935	**0.029**
	Foliage	4672	500	10862	658	**< 0.001**
	Branches	6752	734	15832	971	**< 0.001**
	Bark	3331	424	10210	757	**< 0.001**
	Wood	20597	2721	56245	5509	**0.001**
	Tree Roots	3584	823	5119	648	0.193
	Mid Foliage	4595	1856	0	0	0.090
	Mid Wood	31074	12143	0	0	0.083
	Understory	2568	921	190	73	0.078
	Forest Floor	3566	412	3351	234	0.563
	Veg Roots	931	454	0	0	0.133
	Total Soil	147305	21462	162449	11440	0.394
	0.0-0.2 m	63081	8528	71586	4213	0.385
	0.2-0.4 m	44453	14789	41871	4567	0.873
	0.4-0.6 m	18063	4525	29767	7326	0.224
	0.6-1.0 m	21707	4153	19225	4094	0.685
GF	Total Plant	62473	13548	91719	6620	0.056
	Foliage	4669	806	10329	493	**0.022**
	Branches	5351	1040	12630	678	**0.021**
	Bark	3033	589	7236	388	**0.021**
	Wood	15617	4018	54183	2905	**0.007**
	Tree Roots	1379	229	2323	219	**0.041**
	Mid Foliage	1408	672	0	0	0.171
	Mid Wood	24566	12004	0	0	0.177
	Understory	2224	606	135	38	0.067
	Forest Floor	3388	1169	4883	2459	0.612
	Veg Roots	839	240	0	0	0.073
	Total Soil	193737	29985	166781	20902	0.502
	0.0-0.2 m	92061	19970	77568	1826	0.510
	0.2-0.4 m	43282	1088	39658	8843	0.714
	0.4-0.6 m	29312	2928	30902	9338	0.879
	0.6-1.0 m	29081	9074	18653	4940	0.402

Appendix Table A19

Mass (kg ha^{-1}) of calcium (Ca) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	463.9	30.0	459.1	33.9	437.2	14.6	505.1	34.0	0.079	0.810	0.051
	Foliage	61.9	2.7	74.1	2.9	54.0	0.8	79.2	1.8	**< 0.001**	0.541	**0.014**
	Branches	79.3	3.3	95.1	6.2	49.1	1.0	72.7	1.9	**< 0.001**	**< 0.001**	0.311
	Bark	50.7	2.2	42.8	2.5	43.0	0.7	51.4	1.2	0.884	0.797	**0.001**
	Wood	57.4	3.1	29.8	1.6	21.3	0.3	26.5	0.6	**< 0.001**	**< 0.001**	**< 0.001**
	Tree Roots	30.1	2.3	15.9	1.1	41.2	7.4	22.2	3.3	**0.001**	0.158	0.414
	Mid Foliage	0.0	0.0	0.0	0.0	8.3	5.0	0.0	0.0	0.145	0.145	0.145
	Mid Wood	0.0	0.0	0.0	0.0	15.2	9.3	0.0	0.0	0.153	0.153	0.153
	Understory	23.2	7.5	2.7	1.5	36.0	15.6	1.7	1.0	**0.019**	0.523	0.459
	Forest Floor	161.3	28.7	198.7	30.0	168.6	14.1	251.3	31.5	0.059	0.328	0.413
	Veg Roots	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	**< 0.001**	**< 0.001**	**< 0.001**
	Total Soil	6905	1522	6443	1203	19835	3863	19461	3007	0.826	**0.007**	0.981
	0.0-0.2 m	2229	504	2011	315	4939	774	5287	405	0.897	**0.002**	0.580
	0.2-0.4 m	1579	404	1957	900	4800	906	6126	538	0.166	**0.005**	0.415
	0.4-0.6 m	1600	557	1070	297	3860	834	3519	681	0.369	**0.021**	0.840
	0.6-1.0 m	1497	380	1405	330	6235	1994	4530	1742	0.391	0.053	0.439
WRC	Total Plant	519.3	69.3	673.7	36.2	385.4	51.5	623.4	60.6	**0.007**	0.139	0.482
	Foliage	70.9	24.0	248.9	10.4	85.9	28.5	218.7	14.5	**0.001**	0.754	0.324
	Branches	30.5	11.4	127.4	9.3	42.9	13.9	74.1	5.0	**< 0.001**	0.084	**0.012**
	Bark	23.3	10.6	100.1	18.8	21.3	6.1	47.1	3.1	**< 0.001**	**0.020**	**0.028**
	Wood	10.9	4.0	64.0	4.5	11.0	3.6	25.8	1.7	**< 0.001**	**< 0.001**	**< 0.001**
	Tree Roots	34.1	27.0	51.5	9.8	47.1	4.0	72.6	4.9	0.119	0.206	0.756
	Mid Foliage	63.2	18.2	1.1	1.1	12.4	7.3	4.1	4.1	**0.003**	**0.026**	**0.015**
	Mid Wood	108.6	32.9	2.4	2.4	6.8	3.2	0.8	0.8	**0.009**	**0.015**	**0.014**
	Understory	53.6	27.0	26.9	12.1	100.8	24.2	23.3	5.4	**0.022**	0.284	0.215
	Forest Floor	97.3	37.6	51.0	26.3	54.9	12.5	157.0	43.5	0.280	0.468	**0.024**
	Veg Roots	26.9	5.5	0.2	0.2	2.3	0.9	0.0	0.0	**0.001**	**0.004**	**0.003**
	Total Soil	7309	1027	5479	866	21106	3004	21162	4753	0.798	**0.001**	0.785
	0.0-0.2 m	2152	787	2169	587	6035	1029	4711	267	0.387	**0.011**	0.376
	0.2-0.4 m	1964	162	1308	341	4724	598	3836	599	**0.046**	**0.012**	0.708
	0.4-0.6 m	1597	296	705	19	4414	333	3975	538	0.123	**< 0.001**	0.579
	0.6-1.0 m	1597	111	1296	130	5932	1385	8640	3953	0.638	**0.040**	0.557

Appendix Table A20

Mass (kg ha^{-1}) of calcium (Ca) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	480.5	41.6	554.4	38.7	**0.015**
	Foliage	54.7	5.9	167.2	10.1	**< 0.001**
	Branches	36.4	4.0	90.6	5.6	**< 0.001**
	Bark	24.5	3.1	99.2	7.4	**< 0.001**
	Wood	36.9	4.9	77.3	7.6	**0.004**
	Tree Roots	50.5	11.9	54.5	10.5	0.812
	Mid Foliage	71.2	26.9	0.0	0.0	0.078
	Mid Wood	75.1	30.8	0.0	0.0	0.093
	Understory	51.3	20.2	3.5	1.5	0.099
	Forest Floor	67.3	12.0	62.1	8.3	0.724
	Veg Roots	12.4	5.2	0.0	0.0	0.099
	Total Soil	5056	916	5051	602	0.996
	0.0-0.2 m	1464	337	1583	302	0.801
	0.2-0.4 m	1293	560	1251	242	0.947
	0.4-0.6 m	1224	381	930	128	0.493
	0.6-1.0 m	1076	84	1287	145	0.221
GF	Total Plant	590.2	45.4	810.0	131.7	0.190
	Foliage	120.2	20.7	245.7	11.7	**0.028**
	Branches	50.2	9.8	128.5	6.9	**0.017**
	Bark	56.3	10.9	87.2	4.7	0.102
	Wood	30.4	7.8	93.3	5.0	**0.009**
	Tree Roots	26.7	5.4	34.1	3.2	0.306
	Mid Foliage	36.6	17.5	0.0	0.0	0.171
	Mid Wood	67.7	33.0	0.0	0.0	0.177

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Appendix Table A20 (*continued*)

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
	Understory	36.3	14.3	3.1	1.0	0.133
	Forest Floor	149.4	61.8	218.2	101.7	0.594
	Veg Roots	16.4	5.2	0.0	0.0	0.088
	Total Soil	9896	1921	7642	951	0.155
	0.0-0.2 m	2604	432	2658	400	0.931
	0.2-0.4 m	1924	403	1692	605	0.753
	0.4-0.6 m	2112	607	1137	280	0.152
	0.6-1.0 m	3256	1336	2156	565	0.300

Appendix Table A21

Mass (kg ha^{-1}) of copper (Cu) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	0.366	0.017	0.360	0.026	0.383	0.018	0.466	0.022	**0.022**	0.064	**0.012**
	Foliage	0.031	0.001	0.036	0.001	0.027	0.000	0.039	0.001	**< 0.001**	0.597	**0.006**
	Branches	0.092	0.004	0.102	0.007	0.056	0.001	0.086	0.002	**< 0.001**	**< 0.001**	**0.022**
	Bark	0.049	0.002	0.067	0.004	0.045	0.001	0.070	0.002	**< 0.001**	0.769	0.165
	Wood	0.065	0.003	0.055	0.003	0.076	0.001	0.147	0.003	**< 0.001**	**< 0.001**	**< 0.001**
	Tree Roots	0.046	0.009	0.025	0.004	0.038	0.006	0.022	0.004	**0.004**	0.510	0.538
	Mid Foliage	0.000	0.000	0.000	0.000	0.004	0.002	0.000	0.000	0.127	0.127	0.127
	Mid Wood	0.000	0.000	0.000	0.000	0.027	0.016	0.000	0.000	0.142	0.142	0.142
	Understory	0.025	0.011	0.003	0.002	0.016	0.004	0.001	0.001	**0.011**	0.389	0.534
	Forest Floor	0.058	0.012	0.073	0.015	0.094	0.012	0.101	0.014	0.352	0.076	0.726
	Veg Roots	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**< 0.001**	**< 0.001**	**< 0.001**
	Total Soil	191.6	15.7	204.1	25.9	274.6	25.8	366.5	31.0	**0.014**	**0.009**	**0.040**
	0.0-0.2 m	31.7	2.1	35.5	4.8	45.4	5.9	52.5	4.6	0.172	**0.030**	0.659
	0.2-0.4 m	35.1	4.1	38.0	3.9	55.8	6.7	72.0	6.3	**0.013**	**0.008**	0.051
	0.4-0.6 m	40.1	4.3	43.3	6.0	67.6	10.2	76.6	10.1	0.309	**0.023**	0.612
	0.6-1.0 m	84.6	6.8	87.3	11.9	105.9	9.9	165.5	13.5	**0.002**	**0.012**	**0.003**
WRC	Total Plant	0.423	0.053	0.287	0.014	0.217	0.027	0.271	0.019	0.181	**0.022**	**0.015**
	Foliage	0.023	0.008	0.061	0.003	0.027	0.009	0.059	0.004	**0.003**	0.890	0.691
	Branches	0.017	0.006	0.061	0.004	0.011	0.004	0.028	0.002	**< 0.001**	**0.001**	**0.007**
	Bark	0.006	0.003	0.028	0.005	0.008	0.002	0.021	0.001	**< 0.001**	0.393	0.142
	Wood	0.011	0.004	0.034	0.002	0.013	0.004	0.027	0.002	**< 0.001**	0.503	0.228
	Tree Roots	0.027	0.018	0.059	0.018	0.058	0.004	0.075	0.007	**0.050**	0.145	0.449
	Mid Foliage	0.035	0.010	0.002	0.002	0.006	0.004	0.001	0.001	**0.010**	**0.037**	**0.029**
	Mid Wood	0.200	0.054	0.006	0.006	0.013	0.007	0.001	0.001	**0.005**	**0.011**	**0.009**
	Understory	0.026	0.009	0.018	0.009	0.051	0.015	0.015	0.002	0.055	0.325	0.198
	Forest Floor	0.045	0.015	0.017	0.010	0.025	0.007	0.044	0.023	0.791	0.819	0.176
	Veg Roots	0.031	0.010	0.000	0.000	0.003	0.001	0.000	0.000	**0.008**	**0.019**	**0.017**
	Total Soil	199.1	3.9	224.6	12.2	342.8	19.5	324.0	17.1	0.841	**< 0.001**	0.203
	0.0-0.2 m	32.1	2.2	37.3	1.0	52.7	2.8	56.4	4.9	0.238	**< 0.001**	0.838
	0.2-0.4 m	41.2	1.9	44.2	1.9	60.2	4.4	63.4	4.5	0.445	**0.001**	0.989
	0.4-0.6 m	42.6	1.5	46.9	3.4	76.8	6.5	75.6	3.2	0.746	**< 0.001**	0.562
	0.6-1.0 m	83.2	0.4	96.2	8.7	153.0	12.8	128.6	20.7	0.711	**0.006**	0.236

Appendix Table A22

Mass (kg ha^{-1}) of copper (Cu) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
WH	Total Plant	0.524	0.057	0.591	0.041	**0.035**
	Foliage	0.031	0.003	0.077	0.005	**< 0.001**
	Branches	0.073	0.008	0.154	0.009	**0.001**
	Bark	0.030	0.004	0.070	0.005	**0.001**
	Wood	0.059	0.008	0.197	0.019	**0.001**
	Tree Roots	0.049	0.007	0.062	0.010	0.360
	Mid Foliage	0.037	0.013	0.000	0.000	0.069
	Mid Wood	0.150	0.061	0.000	0.000	0.092

(*continued on next page*)

Appendix Table A22 (*continued*)

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
	Understory	0.039	0.016	0.001	0.001	0.055
	Forest Floor	0.041	0.010	0.029	0.007	0.391
	Veg Roots	0.015	0.007	0.000	0.000	0.112
	Total Soil	192.6	15.2	202.5	16.9	0.504
	0.0-0.2 m	31.6	2.5	31.1	2.8	0.837
	0.2-0.4 m	41.1	2.6	40.1	4.8	0.809
	0.4-0.6 m	40.0	3.5	45.4	3.4	0.268
	0.6-1.0 m	79.9	8.0	86.0	7.1	0.268
GF	Total Plant	0.401	0.072	0.638	0.038	**0.031**
	Foliage	0.035	0.006	0.076	0.004	**0.022**
	Branches	0.050	0.010	0.232	0.012	**0.006**
	Bark	0.032	0.006	0.052	0.003	0.078
	Wood	0.049	0.013	0.196	0.011	**0.005**
	Tree Roots	0.026	0.006	0.041	0.011	0.310
	Mid Foliage	0.018	0.009	0.000	0.000	0.172
	Mid Wood	0.116	0.057	0.000	0.000	0.178
	Understory	0.026	0.004	0.002	0.001	**0.017**
	Forest Floor	0.034	0.010	0.040	0.017	0.787
	Veg Roots	0.015	0.003	0.000	0.000	**0.044**
	Total Soil	212.2	6.5	221.3	3.4	0.124
	0.0-0.2 m	27.2	2.3	31.9	2.1	0.217
	0.2-0.4 m	39.7	1.0	37.3	0.6	0.107
	0.4-0.6 m	48.4	3.1	48.9	0.3	0.883
	0.6-1.0 m	97.0	9.9	103.2	1.2	0.568

Appendix Table A23

Mass (kg ha^{-1}) of Fe of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	45.346	2.027	42.428	2.978	39.351	4.777	44.703	5.97	0.778	0.668	0.347
	Foliage	0.445	0.019	0.640	0.025	0.455	0.007	0.850	0.02	**< 0.001**	**< 0.001**	**< 0.001**
	Branches	0.742	0.031	0.878	0.057	0.320	0.007	1.057	0.03	**< 0.001**	**0.005**	**< 0.001**
	Bark	0.515	0.022	0.625	0.036	0.662	0.011	1.060	0.03	**< 0.001**	**< 0.001**	**< 0.001**
	Wood	1.043	0.056	1.005	0.054	1.164	0.016	1.930	0.04	**< 0.001**	**< 0.001**	**< 0.001**
	Tree Roots	11.111	2.208	7.013	1.372	10.804	1.359	7.252	1.09	**< 0.001**	0.988	0.581
	Mid Foliage	0.000	0.000	0.000	0.000	0.111	0.068	0.000	0.00	0.157	0.157	0.157
	Mid Wood	0.000	0.000	0.000	0.000	1.147	0.657	0.000	0.00	0.131	0.131	0.131
	Understory	2.254	1.167	0.367	0.187	3.811	3.311	0.107	0.09	0.150	0.734	0.611
	Forest Floor	29.236	3.170	31.899	2.439	20.740	2.440	32.446	5.07	0.060	0.272	0.215
	Veg Roots	0.000	0.000	0.000	0.000	0.138	0.027	0.000	0.00	**0.002**	**0.002**	**0.002**
	Total Soil	150073	5082	161559	15321	203747	13008	207794	9115	0.466	**0.007**	0.722
	0.0-0.2 m	26633	1373	28482	1794	33793	2205	35568	1719	0.248	**0.015**	0.980
	0.2-0.4 m	28926	1155	32790	2697	36514	1520	42316	1955	**0.044**	**0.005**	0.629
	0.4-0.6 m	31674	1306	32913	3891	44483	2895	42324	2614	0.874	**0.002**	0.560
	0.6-1.0 m	62840	3151	67375	7249	88957	8039	87587	3714	0.775	**0.012**	0.596
WRC	Total Plant	35.074	8.506	31.568	6.457	33.102	5.334	39.411	3.0	0.260	0.260	0.259
	Foliage	0.348	0.118	0.970	0.041	0.645	0.214	1.549	0.1	**0.003**	**0.043**	0.349
	Branches	0.191	0.071	0.950	0.069	0.360	0.117	0.255	0.0	**0.002**	**0.009**	**< 0.001**
	Bark	0.079	0.036	0.553	0.104	0.154	0.045	0.336	0.0	**< 0.001**	0.224	**0.023**
	Wood	0.154	0.057	1.421	0.099	0.162	0.053	0.537	0.0	**< 0.001**	**< 0.001**	**< 0.001**
	Tree Roots	5.148	3.098	16.042	5.923	13.179	2.055	22.850	4.5	**0.030**	0.098	0.883
	Mid Foliage	0.782	0.255	0.012	0.012	0.113	0.063	0.025	0.0	**0.004**	**0.017**	**0.014**
	Mid Wood	8.723	2.537	0.370	0.370	0.300	0.125	0.014	0.0	**0.007**	**0.013**	**0.009**
	Understory	4.077	1.794	5.130	2.765	11.874	6.385	0.862	0.2	0.244	0.670	0.165
	Forest Floor	9.084	3.671	6.034	3.075	5.738	1.763	12.982	4.8	0.532	0.674	0.160
	Veg Roots	6.487	2.866	0.088	0.088	0.576	0.182	0.000	0.0	**0.031**	0.060	0.055
	Total Soil	150330	5140	157441	9280	207275	10015	209744	4039	0.552	**< 0.001**	0.772
	0.0-0.2 m	23790	950	27919	1813	37093	3065	39445	1696	0.179	**< 0.001**	0.700
	0.2-0.4 m	29725	264	31938	1164	36656	2248	39241	2568	0.276	**0.007**	0.930
	0.4-0.6 m	30587	46	33216	1613	44136	2194	44336	1904	0.461	**< 0.001**	0.526
	0.6-1.0 m	66229	4245	64369	5246	89390	4586	86722	3300	0.616	**< 0.001**	0.928

Appendix Table A24
Mass (kg ha^{-1}) of Fe of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	**Tissue**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**Trt**
WH	Total Plant	38.933	2.642	33.675	3.276	0.163
	Foliage	0.403	0.043	1.494	0.090	**< 0.001**
	Branches	0.376	0.041	1.144	0.070	**< 0.001**
	Bark	0.271	0.034	1.220	0.090	**< 0.001**
	Wood	1.130	0.149	1.595	0.156	0.075
	Tree Roots	15.211	4.318	18.539	3.822	0.585
	Mid Foliage	0.757	0.282	0.000	0.000	0.075
	Mid Wood	5.382	2.207	0.000	0.000	0.093
	Understory	3.531	1.648	0.545	0.232	0.123
	Forest Floor	7.791	1.997	9.137	3.677	0.714
	Veg Roots	4.082	1.661	0.000	0.000	0.091
	Total Soil	166737	8466	163495	6981	0.710
	0.0-0.2 m	26717	1759	26586	1213	0.944
	0.2-0.4 m	34988	1307	32744	2432	0.448
	0.4-0.6 m	34150	2727	34456	1817	0.897
	0.6-1.0 m	70881	5242	69708	3292	0.794
GF	Total Plant	33.872	2.134	33.147	5.395	0.894
	Foliage	0.722	0.125	1.472	0.070	**0.028**
	Branches	0.492	0.096	0.930	0.050	**0.044**
	Bark	0.651	0.127	1.505	0.081	**0.023**
	Wood	0.403	0.104	3.031	0.163	**0.002**
	Tree Roots	6.542	0.062	12.625	2.457	0.069
	Mid Foliage	0.497	0.237	0.000	0.000	0.170
	Mid Wood	4.912	2.412	0.000	0.000	0.179
	Understory	3.220	2.623	0.520	0.171	0.389
	Forest Floor	11.724	2.187	13.064	5.456	0.831
	Veg Roots	4.709	2.246	0.000	0.000	0.171
	Total Soil	158991	19919	172074	1283	0.548
	0.0-0.2 m	22282	3158	27109	1280	0.292
	0.2-0.4 m	29419	1802	30560	1676	0.667
	0.4-0.6 m	35988	4784	36546	872	0.908
	0.6-1.0 m	71303	10270	77858	631	0.559

Appendix Table A25
Mass (kg ha^{-1}) of potassium (K) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	**Tissue**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**Trt**	**Site**	**Site*Trt**
DF	Total Plant	264.17	25.69	245.63	7.80	260.17	20.55	241.28	10.13	0.298	0.831	0.992
	Foliage	63.98	2.79	57.69	2.28	64.59	1.01	80.77	1.88	**0.036**	**< 0.001**	**< 0.001**
	Branches	52.91	2.18	63.29	4.10	44.66	0.95	54.72	1.47	**0.001**	**0.005**	0.949
	Bark	35.95	1.53	53.16	3.08	24.26	0.39	30.63	0.73	**< 0.001**	**< 0.001**	**< 0.001**
	Wood	19.97	1.07	24.87	1.33	14.14	0.19	22.37	0.48	**< 0.001**	**0.001**	0.087
	Tree Roots	16.51	2.23	11.25	4.12	5.56	1.16	3.39	0.99	**0.046**	**0.024**	0.338
	Mid Foliage	0.00	0.00	0.00	0.00	11.10	6.50	0.00	0.00	0.138	0.138	0.138
	Mid Wood	0.00	0.00	0.00	0.00	3.70	2.24	0.00	0.00	0.150	0.150	0.150
	Understory	42.49	21.36	4.82	3.74	48.38	16.12	4.16	3.44	**0.022**	0.857	0.815
	Forest Floor	32.36	1.81	30.56	3.93	43.71	7.03	45.24	6.09	0.972	0.084	0.660
	Veg Roots	0.00	0.00	0.00	0.00	0.07	0.01	0.00	0.00	**< 0.001**	**< 0.001**	**< 0.001**
	Total Soil	12862	840	13086	1673	5264	387	5455	559	0.795	**0.001**	0.983
	0.0-0.2 m	2456	107	2578	366	1253	120	1241	127	0.705	**0.003**	0.648
	0.2-0.4 m	2373	273	2419	418	1145	152	1130	104	0.954	**0.001**	0.910
	0.4-0.6 m	2575	263	2668	353	982	79	1068	130	0.589	**0.002**	0.982
	0.6-1.0 m	5458	280	5421	721	1884	132	2016	273	0.896	**< 0.001**	0.817
WRC	Total Plant	232.77	10.06	165.55	24.37	166.48	28.03	180.57	12.04	0.195	0.336	0.071
	Foliage	21.08	7.15	67.99	2.84	21.24	7.06	78.07	5.17	**< 0.001**	0.465	0.423
	Branches	7.20	2.69	22.14	1.61	10.60	3.43	21.82	1.46	**0.004**	0.581	0.495
	Bark	3.06	1.39	13.01	2.45	3.33	0.96	10.12	0.66	**< 0.001**	0.358	0.275
	Wood	2.61	0.97	9.16	0.64	2.66	0.87	7.22	0.48	**< 0.001**	0.243	0.221
	Tree Roots	10.66	7.92	15.78	1.98	7.60	0.87	8.84	1.18	0.387	0.186	0.594
	Mid Foliage	82.88	24.45	2.10	2.10	12.92	7.45	1.75	1.75	**0.009**	**0.027**	**0.025**
	Mid Wood	28.01	8.13	0.82	0.82	2.64	1.41	0.20	0.20	**0.007**	**0.016**	**0.015**
	Understory	35.44	12.93	26.67	19.44	92.47	31.96	29.94	1.99	0.125	0.188	0.236

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Appendix Table A25 (*continued*)

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
	Forest Floor	31.78	7.05	7.82	3.72	12.65	5.36	22.60	17.50	0.551	0.852	0.165
	Veg Roots	10.04	2.31	0.06	0.06	0.39	0.14	0.00	0.00	**0.003**	**0.005**	**0.004**
	Total Soil	12457	1000	14245	1616	6779	1104	5967	643	0.569	**0.003**	0.166
	0.0-0.2 m	2245	210	2603	292	1850	326	1401	43	0.858	**0.009**	0.132
	0.2-0.4 m	2453	106	2688	243	1171	205	1263	104	0.216	**0.002**	0.562
	0.4-0.6 m	2398	42	2688	228	1198	206	1293	158	0.308	**0.001**	0.591
	0.6-1.0 m	5361	1129	6266	1041	2561	607	2010	358	0.795	**0.010**	0.310

Appendix Table A26
Mass (kg ha^{-1}) of potassium (K) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	329.09	29.38	289.38	19.65	0.275
	Foliage	58.89	6.31	105.17	6.37	**0.002**
	Branches	22.70	2.47	57.75	3.54	**< 0.001**
	Bark	23.55	3.00	52.34	3.88	**0.001**
	Wood	12.97	1.71	35.26	3.45	**0.001**
	Tree Roots	19.44	5.32	22.51	6.85	0.717
	Mid Foliage	81.91	30.19	0.00	0.00	0.073
	Mid Wood	22.49	8.72	0.00	0.00	0.082
	Understory	62.89	35.42	4.57	2.21	0.152
	Forest Floor	19.31	6.56	11.80	1.12	0.302
	Veg Roots	4.95	2.45	0.00	0.00	0.137
	Total Soil	10406	799	11016	706	0.588
	0.0-0.2 m	2080	279	1853	125	0.463
	0.2-0.4 m	2340	227	2183	176	0.605
	0.4-0.6 m	2097	120	2308	202	0.403
	0.6-1.0 m	3889	348	4672	481	0.235
GF	Total Plant	256.56	48.49	354.42	24.67	0.058
	Foliage	41.50	7.16	124.45	5.95	**0.010**
	Branches	31.71	6.16	128.66	6.90	**0.007**
	Bark	24.06	4.67	37.19	2.00	0.103
	Wood	9.91	2.55	34.27	1.84	**0.007**
	Tree Roots	6.44	1.23	12.09	0.45	**0.013**
	Mid Foliage	48.15	23.01	0.00	0.00	0.172
	Mid Wood	16.40	8.01	0.00	0.00	0.177
	Understory	59.97	17.62	2.08	0.56	0.078
	Forest Floor	14.00	3.71	15.68	8.12	0.860
	Veg Roots	4.43	2.04	0.00	0.00	0.162
	Total Soil	13803	1408	14804	1828	0.687
	0.0-0.2 m	2491	469	2484	347	0.992
	0.2-0.4 m	2488	292	2365	62	0.700
	0.4-0.6 m	2719	206	2967	334	0.561
	0.6-1.0 m	6105	939	6987	1152	0.585

Appendix Table A27
Mass (kg ha^{-1}) of magnesium (Mg) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	80.036	3.906	71.016	4.951	63.762	5.269	60.128	4.554	**0.026**	0.074	0.256
	Foliage	11.876	0.518	12.893	0.510	6.835	0.107	12.754	0.297	**< 0.001**	**< 0.001**	**< 0.001**
	Branches	11.791	0.487	10.910	0.708	5.345	0.113	8.828	0.237	**0.013**	**< 0.001**	**< 0.001**
	Bark	7.160	0.304	7.188	0.417	3.463	0.056	5.519	0.131	**0.002**	**< 0.001**	**0.003**
	Wood	7.020	0.375	8.028	0.430	4.468	0.062	5.571	0.119	**0.004**	**< 0.001**	0.874
	Tree Roots	6.876	1.252	3.644	0.583	3.876	0.584	2.281	0.399	**0.001**	0.076	0.088
	Mid Foliage	0.000	0.000	0.000	0.000	2.818	1.731	0.000	0.000	0.155	0.155	0.155
	Mid Wood	0.000	0.000	0.000	0.000	3.588	1.986	0.000	0.000	0.121	0.121	0.121

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Appendix Table A27 (*continued*)

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	**Tissue**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**Trt**	**Site**	**Site*Trt**
	Understory	8.279	2.391	0.913	0.567	7.827	2.045	0.501	0.290	**0.002**	0.812	0.990
	Forest Floor	27.033	3.575	27.441	4.968	25.494	3.699	24.674	3.980	0.957	0.648	0.872
	Veg Roots	0.000	0.000	0.000	0.000	0.048	0.008	0.000	0.000	**0.001**	**0.001**	**0.001**
	Total Soil	23378	1103	24620	1522	11145	706	12066	1769	0.381	**< 0.001**	0.893
	0.0-0.2 m	4230	83	4358	246	1914	137	2205	187	0.245	**< 0.001**	0.635
	0.2-0.4 m	4410	274	4918	365	2130	174	2795	243	0.052	**< 0.001**	0.779
	0.4-0.6 m	4799	282	5095	418	2361	183	2444	385	0.439	**0.001**	0.660
	0.6-1.0 m	9940	621	10249	782	4740	510	4621	999	0.894	**0.001**	0.765
WRC	Total Plant	100.596	8.204	67.493	7.248	48.072	8.762	50.405	5.531	**0.037**	**0.014**	**0.022**
	Foliage	8.620	2.923	21.312	0.892	5.469	1.817	13.451	0.890	**< 0.001**	**0.010**	0.209
	Branches	1.987	0.741	7.668	0.558	2.166	0.701	3.899	0.261	**< 0.001**	**0.012**	**0.007**
	Bark	1.216	0.551	4.594	0.865	1.114	0.322	2.745	0.180	**< 0.001**	0.070	0.100
	Wood	1.471	0.545	6.497	0.455	1.440	0.467	3.557	0.238	**< 0.001**	**0.006**	**0.007**
	Tree Roots	6.335	5.129	11.737	2.344	4.948	0.441	7.515	0.639	0.128	0.270	0.569
	Mid Foliage	19.919	6.589	0.492	0.492	2.217	1.191	0.449	0.449	**0.013**	**0.029**	**0.026**
	Mid Wood	26.693	6.410	0.705	0.705	1.295	0.601	0.098	0.098	**0.003**	**0.006**	**0.005**
	Understory	10.304	3.857	8.713	5.323	22.584	10.428	6.863	1.396	0.232	0.461	0.324
	Forest Floor	19.176	4.850	5.724	2.897	6.589	1.911	11.828	6.942	0.419	0.521	0.084
	Veg Roots	4.873	0.649	0.052	0.052	0.250	0.095	0.000	0.000	**< 0.001**	**0.001**	**< 0.001**
	Total Soil	20360	59	24900	1303	11806	1450	13150	1517	0.055	**< 0.001**	0.266
	0.0-0.2 m	3693	367	4432	206	2225	223	2224	24	0.125	**< 0.001**	0.125
	0.2-0.4 m	4276	9	5076	328	2239	253	2386	162	0.061	**< 0.001**	0.177
	0.4-0.6 m	4318	71	5088	230	2597	293	2799	317	0.108	**< 0.001**	0.326
	0.6-1.0 m	8073	461	10305	802	4744	761	5740	1055	0.091	**0.001**	0.490

Appendix Table A28

Mass (kg ha^{-1}) of magnesium (Mg) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	**Tissue**	**kg ha^{-1}**	**SE**	**kg ha^{-1}**	**SE**	**Trt**
WH	Total Plant	112.967	11.345	80.196	6.120	**0.045**
	Foliage	12.315	1.319	21.382	1.295	**0.003**
	Branches	5.101	0.555	10.609	0.651	**0.001**
	Bark	3.569	0.454	7.882	0.584	**0.001**
	Wood	7.272	0.961	15.174	1.486	**0.004**
	Tree Roots	11.342	2.824	13.228	2.670	0.645
	Mid Foliage	17.132	6.419	0.000	0.000	0.076
	Mid Wood	17.307	7.168	0.000	0.000	0.095
	Understory	21.426	10.233	1.146	0.528	0.095
	Forest Floor	14.828	2.827	10.775	3.064	0.369
	Veg Roots	2.676	1.088	0.000	0.000	0.091
	Total Soil	19369	1410	21577	1257	0.284
	0.0-0.2 m	3460	267	3517	108	0.840
	0.2-0.4 m	4283	191	4383	435	0.839
	0.4-0.6 m	4284	294	4473	360	0.698
	0.6-1.0 m	7342	952	9204	682	0.207
GF	Total Plant	90.516	10.399	93.593	11.013	0.443
	Foliage	13.131	2.266	26.245	1.254	**0.030**
	Branches	4.798	0.932	17.950	0.963	**0.008**
	Bark	4.007	0.778	7.493	0.402	**0.046**
	Wood	5.266	1.355	17.812	0.955	**0.007**
	Tree Roots	5.402	0.743	8.650	0.662	**0.031**
	Mid Foliage	12.626	6.010	0.000	0.000	0.171
	Mid Wood	14.978	7.390	0.000	0.000	0.180
	Understory	14.914	3.001	0.668	0.181	**0.039**
	Forest Floor	11.959	3.298	14.775	7.294	0.743
	Veg Roots	3.435	1.187	0.000	0.000	0.102
	Total Soil	25729	2444	26207	345	0.856
	0.0-0.2 m	3648	465	4346	400	0.319
	0.2-0.4 m	5098	209	4621	157	0.128
	0.4-0.6 m	5563	594	5706	66	0.823
	0.6-1.0 m	11420	1542	11534	201	0.945

Appendix Table A29
Mass (kg ha^{-1}) of manganese (Mn) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	21.384	1.902	25.342	3.454	28.980	2.242	36.895	2.661	0.060	**0.012**	0.471
	Foliage	2.996	0.131	4.464	0.177	3.725	0.058	5.275	0.123	**< 0.001**	**< 0.001**	0.755
	Branches	2.919	0.120	2.936	0.190	2.040	0.043	3.061	0.082	**0.001**	**0.009**	**0.001**
	Bark	1.534	0.065	1.709	0.099	2.324	0.038	2.433	0.058	0.061	**< 0.001**	0.636
	Wood	0.768	0.041	1.177	0.063	1.572	0.022	1.723	0.037	**< 0.001**	**< 0.001**	**0.011**
	Tree Roots	1.434	0.280	1.053	0.175	3.525	0.308	2.164	0.268	**0.001**	**0.003**	**0.015**
	Mid Foliage	0.000	0.000	0.000	0.000	0.124	0.043	0.000	0.000	**0.030**	**0.030**	**0.030**
	Mid Wood	0.000	0.000	0.000	0.000	0.107	0.035	0.000	0.000	**0.022**	**0.022**	**0.022**
	Understory	3.217	2.360	0.244	0.174	1.936	0.643	0.100	0.055	0.080	0.605	0.636
	Forest Floor	8.516	0.889	13.758	3.410	13.582	2.401	22.140	2.160	**0.023**	**0.036**	0.494
	Veg Roots	0.000	0.000	0.000	0.000	0.047	0.010	0.000	0.000	**0.004**	**0.004**	**0.004**
	Total Soil	4742	773	5512	1113	12371	2948	16058	2520	0.299	**0.001**	0.491
	0.0-0.2 m	1617	288	1639	349	4295	529	4615	771	0.743	**0.002**	0.774
	0.2-0.4 m	1282	236	1370	325	3330	631	5187	1339	0.249	**0.009**	0.290
	0.4-0.6 m	1131	226	1139	265	1365	337	2998	651	0.054	0.063	0.056
	0.6-1.0 m	712	95	1365	379	3381	1789	3258	636	0.790	**0.037**	0.696
WRC	Total Plant	9.945	2.483	10.991	1.459	16.592	2.020	20.864	1.223	0.185	**0.008**	0.394
	Foliage	1.000	0.339	3.242	0.136	1.205	0.400	2.927	0.194	**0.001**	0.870	0.408
	Branches	0.205	0.077	0.872	0.064	0.304	0.098	0.490	0.033	**< 0.001**	0.085	**0.009**
	Bark	0.121	0.055	0.528	0.099	0.148	0.043	0.347	0.023	**< 0.001**	0.194	0.092
	Wood	0.100	0.037	0.156	0.011	0.080	0.026	0.179	0.012	**0.008**	0.959	0.379
	Tree Roots	1.152	0.806	3.812	1.392	5.015	0.672	9.205	1.599	**0.019**	**0.004**	0.547
	Mid Foliage	1.525	0.408	0.044	0.044	0.704	0.455	0.189	0.189	**0.015**	0.341	0.184
	Mid Wood	1.135	0.274	0.048	0.048	0.226	0.143	0.030	0.030	**0.005**	**0.030**	**0.022**
	Understory	1.156	0.506	1.140	0.569	5.182	1.224	1.478	0.349	**0.042**	0.066	**0.043**
	Forest Floor	2.400	1.116	1.127	0.737	3.516	1.223	6.018	2.221	0.709	0.090	0.266
	Veg Roots	1.149	0.404	0.021	0.021	0.213	0.065	0.000	0.000	**0.010**	**0.046**	**0.039**
	Total Soil	7481	609	8020	1814	19133	3118	18580	2057	0.997	**0.012**	0.758
	0.0-0.2 m	1742	176	2376	412	5965	1194	7069	474	0.261	**0.004**	0.746
	0.2-0.4 m	2321	26	2267	377	5074	1068	5590	589	0.745	**0.013**	0.690
	0.4-0.6 m	1891	275	1669	392	4297	789	2919	872	0.295	**0.030**	0.443
	0.6-1.0 m	1528	420	1708	653	3797	727	3002	489	0.622	**0.038**	0.443

Appendix Table A30
Mass (kg ha^{-1}) of manganese (Mn) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	29.954	1.734	62.025	5.210	**0.006**
	Foliage	7.584	0.812	23.598	1.429	**< 0.001**
	Branches	2.734	0.297	8.467	0.519	**< 0.001**
	Bark	1.768	0.225	6.475	0.480	**< 0.001**
	Wood	2.217	0.293	10.984	1.076	**< 0.001**
	Tree Roots	2.559	0.548	3.129	0.562	0.496
	Mid Foliage	2.745	1.301	0.000	0.000	0.126
	Mid Wood	1.108	0.519	0.000	0.000	0.123
	Understory	3.496	1.506	0.212	0.077	0.117
	Forest Floor	5.022	1.052	9.160	1.663	0.051
	Veg Roots	0.721	0.294	0.000	0.000	0.092
	Total Soil	5843	1051	5063	451	0.521
	0.0-0.2 m	1426	219	1418	92	0.965
	0.2-0.4 m	1489	344	1498	203	0.982
	0.4-0.6 m	1262	196	1175	236	0.787
	0.6-1.0 m	1666	483	972	143	0.218
GF	Total Plant	21.222	2.812	35.358	6.109	0.103
	Foliage	5.310	0.916	11.573	0.553	**0.023**
	Branches	1.389	0.270	4.167	0.224	**0.012**
	Bark	1.624	0.316	3.684	0.198	**0.024**
	Wood	1.283	0.330	3.634	0.195	**0.012**
	Tree Roots	1.235	0.022	2.320	0.187	**0.024**
	Mid Foliage	0.226	0.127	0.000	0.000	0.217
	Mid Wood	0.292	0.158	0.000	0.000	0.205
	Understory	3.359	2.363	0.129	0.038	0.301

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Appendix Table A30 (*continued*)

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
	Forest Floor	5.627	1.948	9.852	5.046	0.479
	Veg Roots	0.877	0.402	0.000	0.000	0.161
	Total Soil	6400	1517	8119	1613	0.481
	0.0-0.2 m	1500	213	2527	73	**0.010**
	0.2-0.4 m	1814	154	1939	510	0.827
	0.4-0.6 m	1417	403	2021	507	0.404
	0.6-1.0 m	1669	807	1632	538	0.972

Appendix Table A31

Mass (kg ha^{-1}) of nitrogen (N) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	604.66	62.08	687.20	76.06	517.66	34.07	596.37	43.17	0.076	0.252	0.961
	Foliage	129.56	5.65	174.39	6.90	106.05	1.66	155.01	3.61	**< 0.001**	**0.001**	0.681
	Branches	75.65	3.12	86.54	5.61	37.25	0.79	56.78	1.52	**0.001**	**< 0.001**	0.218
	Bark	52.88	2.25	58.80	3.41	30.98	0.50	47.20	1.12	**< 0.001**	**< 0.001**	**0.033**
	Wood	28.29	1.51	34.40	1.84	63.03	0.87	68.03	1.45	**0.003**	**< 0.001**	0.711
	Tree Roots	52.91	8.32	30.59	2.61	34.32	5.21	22.55	3.68	**0.012**	0.066	0.315
	Mid Foliage	0.00	0.00	0.00	0.00	23.00	14.17	0.00	0.00	0.156	0.156	0.156
	Mid Wood	0.00	0.00	0.00	0.00	15.29	7.79	0.00	0.00	0.097	0.097	0.097
	Understory	41.86	12.23	4.10	2.14	39.01	12.41	3.04	1.92	**0.005**	0.837	0.921
	Forest Floor	223.52	64.40	298.38	72.28	168.29	22.35	243.75	36.61	0.181	0.365	0.995
	Veg Roots	0.00	0.00	0.00	0.00	0.43	0.08	0.00	0.00	**0.002**	**0.002**	**0.002**
	Total Soil	9507	640	8859	935	8924	1004	10752	700	0.473	0.491	0.159
	0.0-0.2 m	3545	220	3798	820	3508	515	3482	236	0.827	0.736	0.789
	0.2-0.4 m	2377	253	1882	168	2494	403	3379	511	0.513	0.105	**0.050**
	0.4-0.6 m	2131	308	1100	150	1375	115	1796	134	0.109	0.896	**0.004**
	0.6-1.0 m	1454	133	2079	263	1547	197	2095	392	**0.008**	0.879	0.807
WRC	Total Plant	651.29	104.06	487.51	18.78	332.49	51.96	412.87	26.18	0.436	**0.025**	0.056
	Foliage	61.12	20.72	223.65	9.36	61.61	20.47	122.53	8.11	**0.001**	**0.028**	**0.024**
	Branches	14.18	5.29	50.40	3.67	12.38	4.01	17.59	1.18	**< 0.001**	**0.001**	**0.002**
	Bark	4.43	2.01	20.52	3.86	6.91	2.00	17.36	1.14	**< 0.001**	0.883	0.243
	Wood	9.94	3.68	29.45	2.06	34.63	11.25	84.22	5.63	**0.004**	**0.005**	0.080
	Tree Roots	29.07	20.66	69.09	13.09	38.20	1.17	61.30	8.23	**0.021**	0.961	0.415
	Mid Foliage	173.77	56.23	5.70	5.70	26.59	15.24	3.82	3.82	**0.012**	**0.035**	**0.033**
	Mid Wood	149.94	61.54	15.06	15.06	9.46	5.02	0.58	0.58	**0.017**	0.059	**0.027**
	Understory	70.53	26.58	39.48	17.86	98.42	40.39	30.43	4.43	0.102	0.739	0.517
	Forest Floor	103.93	32.20	33.90	17.50	42.49	10.88	75.05	30.92	0.464	0.710	0.082
	Veg Roots	34.39	9.10	0.27	0.27	1.80	0.62	0.00	0.00	**0.005**	**0.008**	**0.008**
	Total Soil	10548	188	8731	559	10921	1276	9026	501	0.079	0.711	0.965
	0.0-0.2 m	3830	513	3239	276	3434	454	3640	204	0.625	0.994	0.322
	0.2-0.4 m	2829	576	2495	219	2766	511	2380	349	0.252	0.882	0.929
	0.4-0.6 m	2055	381	1389	216	2127	550	1270	69	0.070	0.952	0.804
	0.6-1.0 m	1835	314	1607	70	2593	435	1736	295	0.121	0.296	0.329

Appendix Table A32

Mass (kg ha^{-1}) of nitrogen (N) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
WH	Total Plant	735.25	70.72	596.41	38.64	**0.032**
	Foliage	101.07	10.83	220.21	13.34	**< 0.001**
	Branches	39.09	4.25	86.21	5.29	**< 0.001**
	Bark	20.01	2.54	72.31	5.36	**< 0.001**
	Wood	32.98	4.36	80.51	7.89	**0.002**
	Tree Roots	61.27	16.98	75.00	12.21	0.536
	Mid Foliage	173.75	63.08	0.00	0.00	0.071
	Mid Wood	97.78	30.56	0.00	0.00	**0.049**
	Understory	96.32	39.09	6.11	2.48	0.061

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Appendix Table A32 (*continued*)

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
	Forest Floor	98.06	10.49	56.06	5.55	**0.024**
	Veg Roots	14.93	5.73	0.00	0.00	0.080
	Total Soil	8250	711	9071	754	**0.021**
	0.0-0.2 m	2673	334	2930	276	0.444
	0.2-0.4 m	2378	599	2476	264	0.886
	0.4-0.6 m	1353	233	1982	414	0.213
	0.6-1.0 m	1846	188	1683	193	0.570
GF	Total Plant	579.12	53.80	684.17	82.08	0.107
	Foliage	110.16	19.01	227.86	10.89	**0.027**
	Branches	32.22	6.26	130.64	7.01	**0.007**
	Bark	26.40	5.13	44.76	2.40	0.068
	Wood	31.54	8.11	97.66	5.24	**0.009**
	Tree Roots	31.59	6.70	49.03	7.14	0.149
	Mid Foliage	103.38	49.20	0.00	0.00	0.170
	Mid Wood	61.43	30.48	0.00	0.00	0.181
	Understory	57.88	7.99	4.57	1.61	**0.019**
	Forest Floor	106.38	41.89	129.65	57.90	0.761
	Veg Roots	18.13	3.75	0.00	0.00	**0.040**
	Total Soil	11663	1039	9974	1157	0.338
	0.0-0.2 m	4355	671	3687	99	0.380
	0.2-0.4 m	2752	222	2536	585	0.709
	0.4-0.6 m	2000	96	1935	505	0.906
	0.6-1.0 m	2556	524	1816	255	0.225

Appendix Table A33
Mass (kg ha^{-1}) of sodium (Na) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	12.659	0.370	11.015	0.567	4.752	0.319	5.539	0.626	0.369	**< 0.001**	**0.033**
	Foliage	1.639	0.071	2.975	0.118	0.810	0.013	0.866	0.020	**< 0.001**	**< 0.001**	**< 0.001**
	Branches	1.060	0.044	0.918	0.060	0.048	0.001	0.165	0.004	0.733	**< 0.001**	**0.004**
	Bark	3.947	0.168	1.930	0.112	0.346	0.006	0.735	0.017	**< 0.001**	**< 0.001**	**< 0.001**
	Wood	0.100	0.005	0.124	0.007	0.071	0.001	0.112	0.002	**< 0.001**	**0.001**	0.087
	Tree Roots	1.436	0.561	0.735	0.141	0.562	0.115	0.356	0.082	0.087	0.130	0.307
	Mid Foliage	0.000	0.000	0.000	0.000	0.076	0.039	0.000	0.000	0.101	0.101	0.101
	Mid Wood	0.000	0.000	0.000	0.000	0.018	0.011	0.000	0.000	0.150	0.150	0.150
	Understory	0.633	0.109	0.081	0.048	0.505	0.190	0.039	0.030	**0.002**	0.531	0.672
	Forest Floor	3.843	0.290	4.252	0.572	2.310	0.245	3.266	0.520	0.139	**0.013**	0.538
	Veg Roots	0.000	0.000	0.000	0.000	0.007	0.001	0.000	0.000	**0.003**	**0.003**	**0.003**
	Total Soil	1359.7	50.3	1588.1	107.5	1044.0	84.6	1061.3	84.5	0.171	**< 0.001**	0.234
	0.0-0.2 m	254.0	15.2	282.6	8.2	160.5	11.5	175.5	5.9	0.066	**< 0.001**	0.539
	0.2-0.4 m	255.0	16.8	288.6	22.4	242.9	27.2	301.5	41.2	0.111	0.990	0.630
	0.4-0.6 m	342.3	15.3	428.1	36.4	229.2	14.1	213.3	23.3	0.171	**< 0.001**	0.056
	0.6-1.0 m	508.4	29.9	588.9	56.2	411.4	42.4	371.0	41.6	0.604	**0.019**	0.150
WRC	Total Plant	6.433	1.445	5.938	0.580	3.667	0.614	3.577	0.34	0.713	**0.008**	0.799
	Foliage	0.810	0.275	1.895	0.079	0.394	0.131	1.071	0.07	**< 0.001**	**0.002**	0.200
	Branches	0.078	0.029	0.214	0.016	0.011	0.004	-0.111	0.01	0.666	**< 0.001**	**< 0.001**
	Bark	0.120	0.054	0.520	0.098	0.052	0.015	0.120	0.01	**0.001**	**0.001**	**0.006**
	Wood	0.013	0.005	0.046	0.003	0.013	0.004	0.036	0.00	**< 0.001**	0.243	0.221
	Tree Roots	0.924	0.557	1.634	0.242	0.938	0.248	0.933	0.19	0.288	0.344	0.282
	Mid Foliage	0.767	0.184	0.032	0.032	0.265	0.168	0.024	0.02	**0.012**	0.104	0.108
	Mid Wood	0.209	0.042	0.004	0.004	0.102	0.064	0.004	0.00	**0.005**	0.230	0.233
	Understory	0.732	0.270	0.693	0.376	1.242	0.409	0.321	0.05	0.154	0.830	0.187
	Forest Floor	1.657	0.327	0.893	0.510	0.599	0.101	1.179	0.38	0.778	0.351	0.082
	Veg Roots	1.123	0.564	0.007	0.007	0.050	0.024	0.000	0.00	0.055	0.073	0.071
	Total Soil	1336.3	63.4	1434.7	87.3	1048.9	75.9	1178.2	78.5	0.179	**0.006**	0.849
	0.0-0.2 m	197.7	23.0	231.6	23.3	186.9	12.6	205.0	16.2	0.187	0.331	0.673
	0.2-0.4 m	330.3	27.4	343.1	32.7	264.6	24.7	348.9	15.2	0.078	0.254	0.179
	0.4-0.6 m	279.7	22.3	268.3	19.6	217.6	13.7	225.7	23.7	0.938	**0.028**	0.642
	0.6-1.0 m	528.6	35.2	591.6	23.5	379.9	35.0	398.6	37.9	0.274	**0.001**	0.545

Appendix Table A34
Mass (kg ha^{-1}) of sodium (Na) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	8.096	0.952	8.652	0.488	0.619
	Foliage	1.113	0.119	3.140	0.190	**< 0.001**
	Branches	0.026	0.003	0.224	0.014	**< 0.001**
	Bark	0.632	0.080	1.736	0.129	**< 0.001**
	Wood	0.065	0.009	0.176	0.017	**< 0.001**
	Tree Roots	1.314	0.297	1.941	0.324	0.241
	Mid Foliage	1.220	0.509	0.000	0.000	0.096
	Mid Wood	0.393	0.174	0.000	0.000	0.110
	Understory	1.513	0.670	0.100	0.044	0.080
	Forest Floor	1.468	0.262	1.335	0.161	0.647
	Veg Roots	0.351	0.154	0.000	0.000	0.107
	Total Soil	1277.4	47.2	1320.0	39.1	0.513
	0.0-0.2 m	207.0	16.7	216.3	16.3	0.703
	0.2-0.4 m	301.8	20.9	325.6	33.2	0.566
	0.4-0.6 m	295.6	12.7	301.4	14.6	0.773
	0.6-1.0 m	473.1	29.6	476.7	14.8	0.916
GF	Total Plant	5.420	0.149	6.743	1.090	0.318
	Foliage	0.643	0.111	1.546	0.074	**0.017**
	Branches	0.350	0.068	1.008	0.054	**0.013**
	Bark	0.407	0.079	0.786	0.042	**0.041**
	Wood	0.050	0.013	0.171	0.009	**0.007**
	Tree Roots	0.601	0.083	1.332	0.064	**0.016**
	Mid Foliage	0.302	0.146	0.000	0.000	0.174
	Mid Wood	0.082	0.040	0.000	0.000	0.177
	Understory	1.293	0.399	0.075	0.022	0.084
	Forest Floor	1.275	0.368	1.823	0.855	0.587
	Veg Roots	0.42	0.19	0.00	0.00	0.161
	Total Soil	1624.4	9.1	1501.8	91.9	0.255
	0.0-0.2 m	228.0	10.5	277.7	14.9	0.052
	0.2-0.4 m	363.6	28.4	314.8	22.3	0.220
	0.4-0.6 m	354.6	17.0	338.5	16.2	0.524
	0.6-1.0 m	678.2	32.1	570.8	63.9	0.242

Appendix Table A35
Mass (kg ha^{-1}) of phosphorous (P) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	74.300	3.907	79.466	3.339	70.302	4.202	79.299	2.572	**0.049**	0.632	0.531
	Foliage	18.010	0.785	21.878	0.866	18.315	0.287	23.786	0.554	**< 0.001**	0.121	0.249
	Branches	13.397	0.553	15.471	1.003	10.894	0.231	15.449	0.414	**< 0.001**	0.065	0.069
	Bark	9.210	0.392	11.034	0.640	6.653	0.108	9.323	0.221	**< 0.001**	**< 0.001**	0.305
	Wood	2.556	0.137	2.793	0.150	3.181	0.044	3.169	0.068	0.324	**0.001**	0.277
	Tree Roots	6.643	1.589	4.245	1.051	4.098	0.654	3.374	0.442	**0.022**	0.258	0.153
	Mid Foliage	0.000	0.000	0.000	0.000	2.879	1.812	0.000	0.000	0.163	0.163	0.163
	Mid Wood	0.000	0.000	0.000	0.000	2.322	1.622	0.000	0.000	0.202	0.202	0.202
	Understory	4.569	1.637	0.397	0.206	6.199	2.145	0.461	0.341	**0.010**	0.563	0.581
	Forest Floor	19.915	3.824	23.649	3.344	15.711	0.306	23.737	1.266	**0.045**	0.448	0.429
	Veg Roots	0.000	0.000	0.000	0.000	0.051	0.008	0.000	0.000	**0.001**	**0.001**	**0.001**
	Total Soil	32481	3186	32064	3546	61714	8810	58691	4162	0.757	**< 0.001**	0.814
	0.0-0.2 m	7804	631	8502	924	13261	866	13358	241	0.590	**< 0.001**	0.683
	0.2-0.4 m	8215	1579	6350	717	12287	1476	14327	1719	0.952	**< 0.001**	0.196
	0.4-0.6 m	7870	1082	5898	753	11021	1171	10759	1002	0.292	**0.002**	0.415
	0.6-1.0 m	8591	820	11315	1480	25146	7866	20247	1641	0.796	**0.009**	0.372
WRC	Total Plant	72.723	4.725	56.488	4.241	39.545	8.251	49.077	3.424	0.590	**0.020**	0.078
	Foliage	7.894	2.677	22.231	0.930	6.713	2.231	17.710	1.172	**0.001**	0.205	0.408
	Branches	1.691	0.631	7.411	0.540	2.461	0.797	6.266	0.419	**0.001**	0.781	0.190
	Bark	1.005	0.455	3.601	0.678	1.181	0.341	3.002	0.196	**0.000**	0.620	0.371
	Wood	0.436	0.161	1.678	0.117	0.599	0.195	1.383	0.092	**0.001**	0.686	0.190
	Tree Roots	4.717	3.484	9.119	0.115	4.561	0.370	9.451	1.550	**0.023**	0.961	0.891
	Mid Foliage	21.061	6.690	0.285	0.285	3.842	2.238	0.502	0.502	**0.003**	**0.021**	**0.019**
	Mid Wood	15.969	6.212	0.258	0.258	1.345	0.671	0.070	0.070	**0.023**	**0.038**	**0.040**
	Understory	7.314	3.082	5.857	3.073	14.269	5.942	5.022	0.977	0.211	0.462	0.353

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Appendix Table A35 (*continued*)

Species	Tissue	CR				CF				P-value		
		Control		VM		Control		VM				
		kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
	Forest Floor	7.971	1.565	6.020	3.735	4.366	1.698	5.673	0.712	0.806	0.475	0.248
	Veg Roots	4.666	0.990	0.028	0.028	0.208	0.070	0.000	0.000	**0.002**	**0.003**	**0.003**
	Total Soil	38755	1617	40669	2259	56620	8674	56363	9748	0.606	0.186	0.503
	0.0-0.2 m	9593	713	12000	1084	15813	3144	17225	2717	0.262	0.136	0.756
	0.2-0.4 m	9249	1248	9704	761	11344	1779	12811	2017	0.416	0.281	0.660
	0.4-0.6 m	8193	8	7583	185	11393	2434	9293	1356	0.260	0.290	0.516
	0.6-1.0 m	11720	612	11382	594	18070	2780	17034	4449	0.800	0.156	0.897

Appendix Table A36

Mass (kg ha^{-1}) of phosphorous (P) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

Species	Tissue	Control		VM		P-value
		kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	113.155	8.902	116.901	6.498	0.224
	Foliage	26.607	2.850	50.638	3.067	**0.001**
	Branches	6.255	0.680	15.122	0.928	**< 0.001**
	Bark	6.718	0.854	17.353	1.287	**0.001**
	Wood	4.513	0.596	12.106	1.186	**0.001**
	Tree Roots	9.676	2.410	11.904	1.506	0.432
	Mid Foliage	23.183	8.758	0.000	0.000	0.077
	Mid Wood	13.508	5.514	0.000	0.000	0.092
	Understory	11.101	5.278	0.701	0.270	0.097
	Forest Floor	9.316	1.427	9.076	1.235	0.858
	Veg Roots	2.278	0.942	0.000	0.000	0.094
	Total Soil	39350	6339	37657	3740	0.756
	0.0-0.2 m	9713	2367	9221	1155	0.828
	0.2-0.4 m	10233	2860	9892	2072	0.926
	0.4-0.6 m	8314	760	8027	860	0.811
	0.6-1.0 m	11090	1627	10517	914	0.502
GF	Total Plant	76.268	15.253	103.996	8.215	0.121
	Foliage	13.061	2.254	32.967	1.575	**0.015**
	Branches	7.351	1.428	30.762	1.651	**0.006**
	Bark	5.055	0.982	8.138	0.437	0.085
	Wood	2.064	0.531	8.281	0.444	**0.005**
	Tree Roots	4.915	0.989	10.133	3.120	0.186
	Mid Foliage	13.094	6.221	0.000	0.000	0.170
	Mid Wood	11.301	5.440	0.000	0.000	0.173
	Understory	7.466	1.835	0.494	0.159	**0.019**
	Forest Floor	8.756	1.982	13.221	6.050	0.522
	Veg Roots	3.204	1.281	0.000	0.000	0.130
	Total Soil	41366	11310	44789	6587	0.807
	0.0-0.2 m	10106	2656	12787	1684	0.442
	0.2-0.4 m	8053	552	9868	2772	0.556
	0.4-0.6 m	8955	2451	9006	1781	0.988
	0.6-1.0 m	14252	6030	13128	498	0.862

Appendix Table A37

Mass (kg ha^{-1}) of Sulfur (S) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

Species	Tissue	CR				CF				P-value		
		Control		VM		Control		VM				
		kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	95.88	4.66	109.84	8.63	82.23	10.65	91.97	3.27	0.085	0.123	0.726
	Foliage	13.35	0.58	19.96	0.79	9.86	0.15	13.72	0.32	**< 0.001**	**< 0.001**	**0.022**
	Branches	14.69	0.61	16.71	1.08	8.17	0.17	13.19	0.35	**< 0.001**	**< 0.001**	**0.040**
	Bark	10.12	0.43	9.64	0.56	5.94	0.10	8.54	0.20	**0.014**	**< 0.001**	**0.001**
	Wood	21.30	1.14	27.98	1.50	14.26	0.20	24.60	0.52	**< 0.001**	**< 0.001**	0.086
	Tree Roots	6.65	1.42	4.17	0.65	4.41	0.99	3.21	0.52	**0.026**	0.232	0.348
	Mid Foliage	0.00	0.00	0.00	0.00	0.59	0.26	0.00	0.00	0.067	0.067	0.067
	Mid Wood	0.00	0.00	0.00	0.00	15.54	10.53	0.00	0.00	0.191	0.191	0.191

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Appendix Table A37 (*continued*)

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
	Understory	5.39	1.61	0.46	0.24	3.97	1.01	0.37	0.24	**0.003**	0.497	0.480
	Forest Floor	24.38	4.81	30.92	7.47	19.44	1.44	28.34	2.28	0.084	0.513	0.762
	Veg Roots	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00	**0.003**	**0.003**	**0.003**
WRC	Total Plant	145.05	31.30	59.85	2.99	37.13	6.03	48.86	3.03	**0.032**	**0.011**	**0.012**
	Foliage	4.76	1.61	11.46	0.48	4.97	1.65	12.59	0.83	**0.002**	0.646	0.723
	Branches	2.57	0.96	9.52	0.69	2.47	0.80	5.45	0.36	**< 0.001**	**0.016**	**0.020**
	Bark	1.19	0.54	5.12	0.96	1.10	0.32	2.80	0.18	**< 0.001**	**0.040**	0.055
	Wood	3.08	1.14	11.06	0.77	3.20	1.04	8.42	0.56	**< 0.001**	0.194	0.159
	Tree Roots	4.03	2.72	9.78	1.18	5.25	0.45	8.82	1.32	**0.025**	0.938	0.490
	Mid Foliage	6.00	1.05	0.15	0.15	2.22	1.42	0.28	0.28	**0.002**	0.088	0.071
	Mid Wood	101.88	39.12	1.30	1.30	2.84	1.22	0.04	0.04	**0.025**	**0.029**	**0.030**
	Understory	7.57	3.40	5.21	2.35	9.46	2.69	2.50	0.43	0.077	0.867	0.354
	Forest Floor	9.24	1.61	6.22	3.79	5.38	1.47	7.97	1.96	0.920	0.681	0.231
	Veg Roots	4.71	1.29	0.04	0.04	0.24	0.08	0.00	0.00	**0.006**	**0.010**	**0.009**

Appendix Table A38

Mass (kg ha^{-1}) of Sulfur (S) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		Control		VM		P-value
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt
WH	Total Plant	143.19	32.94	107.36	7.48	0.258
	Foliage	10.42	1.12	20.17	1.22	**0.001**
	Branches	7.52	0.82	17.00	1.04	**< 0.001**
	Bark	3.89	0.49	12.94	0.96	**< 0.001**
	Wood	13.73	1.81	37.61	3.68	**0.001**
	Tree Roots	7.94	1.27	10.01	1.47	0.328
	Mid Foliage	9.82	4.37	0.00	0.00	0.110
	Mid Wood	68.29	31.85	0.00	0.00	0.121
	Understory	10.30	4.21	0.79	0.30	0.107
	Forest Floor	9.01	0.92	8.84	1.08	0.533
	Veg Roots	2.27	1.00	0.00	0.00	0.109
GF	Total Plant	133.11	35.22	103.53	7.89	0.392
	Foliage	9.75	1.68	19.13	0.91	**0.032**
	Branches	6.10	1.19	19.08	1.02	**0.011**
	Bark	4.03	0.78	8.23	0.44	**0.034**
	Wood	10.98	2.83	38.84	2.08	**0.006**
	Tree Roots	4.20	0.75	6.53	0.94	0.124
	Mid Foliage	2.12	1.04	0.00	0.00	0.178
	Mid Wood	74.09	35.78	0.00	0.00	0.174
	Understory	9.83	3.40	0.51	0.14	0.104
	Forest Floor	9.34	2.50	11.21	4.36	0.728
	Veg Roots	2.67	0.96	0.00	0.00	0.109

Appendix Table A39

Mass (kg ha^{-1}) of zinc (Zn) of tree and ecosystem components for 19-year-old Douglas-fir (DF) and western redcedar (WRC) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

		CR				CF				P-value		
		Control		VM		Control		VM				
Species	Tissue	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE	Trt	Site	Site*Trt
DF	Total Plant	1.460	0.094	1.569	0.114	1.238	0.020	1.579	0.081	**0.008**	0.355	0.090
	Foliage	0.122	0.005	0.135	0.005	0.107	0.002	0.147	0.003	**< 0.001**	0.768	**0.007**
	Branches	0.432	0.018	0.498	0.032	0.251	0.005	0.345	0.009	**0.001**	**< 0.001**	0.478
	Bark	0.263	0.011	0.342	0.020	0.218	0.004	0.296	0.007	**< 0.001**	**0.003**	0.956
	Wood	0.245	0.013	0.249	0.013	0.218	0.003	0.366	0.008	**< 0.001**	**0.001**	**< 0.001**
	Tree Roots	0.089	0.012	0.062	0.008	0.074	0.006	0.046	0.006	**0.009**	0.167	0.957
	Mid Foliage	0.000	0.000	0.000	0.000	0.010	0.005	0.000	0.000	0.084	0.084	0.084
	Mid Wood	0.000	0.000	0.000	0.000	0.031	0.018	0.000	0.000	0.141	0.141	0.141
	Understory	0.081	0.043	0.010	0.007	0.059	0.018	0.008	0.005	**0.023**	0.616	0.670
	Forest Floor	0.228	0.055	0.274	0.062	0.269	0.039	0.371	0.064	0.196	0.298	0.600
	Veg Roots	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	**0.006**	**0.006**	**0.006**

(*continued on next page*)

Appendix Table A39 (*continued*)

Species	Tissue	CR Control kg ha^{-1}	CR Control SE	CR VM kg ha^{-1}	CR VM SE	CF Control kg ha^{-1}	CF Control SE	CF VM kg ha^{-1}	CF VM SE	P-value Trt	P-value Site	P-value Site*Trt
	Total Soil	437.1	20.2	482.7	73.7	430.4	75.6	468.6	88.9	0.559	0.889	0.959
	0.0-0.2 m	86.0	4.8	100.8	15.0	89.2	8.8	97.4	17.5	0.350	0.993	0.778
	0.2-0.4 m	92.1	5.4	94.9	13.5	87.9	8.3	114.3	22.3	0.305	0.627	0.401
	0.4-0.6 m	98.6	3.9	99.2	18.8	84.6	10.2	91.8	18.5	0.780	0.507	0.815
	0.6-1.0 m	160.5	15.5	187.7	29.8	168.7	50.6	165.2	33.2	0.736	0.847	0.664
WRC	Total Plant	0.924	0.104	0.884	0.067	0.783	0.234	0.858	0.066	0.908	0.631	0.702
	Foliage	0.100	0.034	0.247	0.010	0.092	0.031	0.216	0.014	**0.002**	0.488	0.651
	Branches	0.057	0.021	0.182	0.013	0.050	0.016	0.088	0.006	**< 0.001**	**0.007**	**0.014**
	Bark	0.036	0.016	0.114	0.022	0.026	0.008	0.058	0.004	**0.001**	**0.025**	0.089
	Wood	0.018	0.006	0.076	0.005	0.026	0.008	0.073	0.005	**0.001**	0.726	0.434
	Tree Roots	0.070	0.050	0.128	0.029	0.252	0.129	0.215	0.046	0.862	0.259	0.442
	Mid Foliage	0.096	0.023	0.005	0.005	0.024	0.015	0.009	0.009	**0.004**	**0.036**	**0.024**
	Mid Wood	0.273	0.077	0.014	0.014	0.038	0.023	0.002	0.002	**0.006**	**0.025**	**0.017**
	Understory	0.079	0.031	0.046	0.023	0.158	0.064	0.061	0.008	0.153	0.282	0.457
	Forest Floor	0.115	0.039	0.070	0.035	0.102	0.031	0.134	0.061	0.889	0.595	0.420
	Veg Roots	0.081	0.020	0.001	0.001	0.015	0.010	0.000	0.000	**0.006**	**0.023**	**0.024**
	Total Soil	443.3	46.9	499.8	42.7	484.8	55.2	554.5	43.3	0.059	0.490	0.808
	0.0-0.2 m	85.2	7.9	104.5	11.9	116.3	19.3	129.1	4.3	0.248	0.101	0.800
	0.2-0.4 m	111.3	7.2	109.6	8.0	100.6	14.3	115.5	3.8	0.509	0.826	0.414
	0.4-0.6 m	110.0	12.8	105.4	9.9	102.5	12.4	111.3	5.2	0.801	0.952	0.448
	0.6-1.0 m	136.9	23.2	180.2	14.7	165.4	14.7	198.6	33.3	**0.034**	0.496	0.718

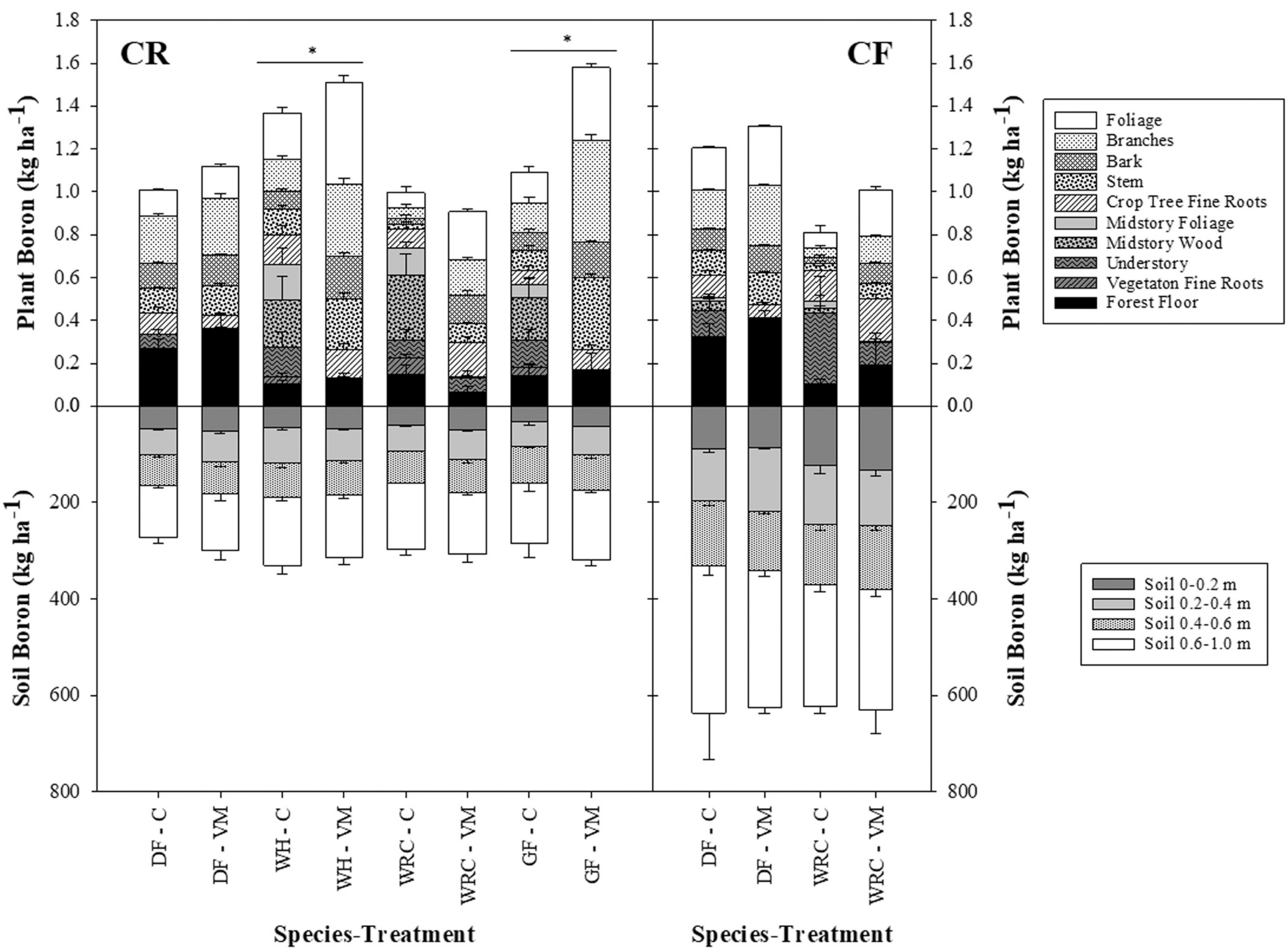
Appendix Table A40

Mass (kg ha^{-1}) of zinc (Zn) of tree and ecosystem components for 19-year-old western hemlock (WH) and grand fir (GF) stands growing under contrasting treatments of vegetation management on sites located in the central Coast Range of western Oregon. SE is the standard error. The P-value shown is in bold if the difference in concentration was significant at α = 0.05.

Species	Tissue	Control kg ha^{-1}	Control SE	VM kg ha^{-1}	VM SE	P-value Trt
WH	Total Plant	1.297	0.103	1.228	0.104	0.575
	Foliage	0.111	0.012	0.227	0.014	**0.001**
	Branches	0.141	0.015	0.245	0.015	**0.003**
	Bark	0.050	0.006	0.118	0.009	**0.001**
	Wood	0.158	0.021	0.372	0.036	**0.002**
	Tree Roots	0.117	0.028	0.158	0.041	0.446
	Mid Foliage	0.122	0.049	0.000	0.000	0.091
	Mid Wood	0.270	0.108	0.000	0.000	0.089
	Understory	0.174	0.089	0.006	0.002	0.108
	Forest Floor	0.127	0.021	0.102	0.014	0.354
	Veg Roots	0.028	0.012	0.000	0.000	0.095
	Total Soil	479.1	20.7	471.8	31.5	0.816
	0.0-0.2 m	91.3	8.9	90.5	3.5	0.919
	0.2-0.4 m	113.2	7.8	105.4	13.1	0.626
	0.4-0.6 m	105.9	3.7	103.9	7.0	0.809
	0.6-1.0 m	168.7	15.7	172.1	10.9	0.749
GF	Total Plant	1.215	0.181	1.972	0.232	0.051
	Foliage	0.237	0.041	0.531	0.025	**0.021**
	Branches	0.162	0.032	0.460	0.025	**0.013**
	Bark	0.116	0.022	0.136	0.007	0.454
	Wood	0.144	0.037	0.420	0.023	**0.011**
	Tree Roots	0.072	0.013	0.136	0.020	**0.027**
	Mid Foliage	0.038	0.019	0.000	0.000	0.176
	Mid Wood	0.137	0.067	0.000	0.000	0.178
	Understory	0.087	0.037	0.006	0.003	0.098
	Forest Floor	0.177	0.059	0.283	0.152	0.549
	Veg Roots	0.046	0.017	0.000	0.000	0.115
	Total Soil	567.6	18.4	571.6	57.1	0.952
	0.0-0.2 m	91.1	8.1	117.6	3.9	0.071
	0.2-0.4 m	132.7	12.8	113.6	19.7	0.255
	0.4-0.6 m	127.0	3.1	135.5	17.2	0.638
	0.6-1.0 m	216.9	21.1	204.9	17.3	0.682

Appendix Table A41
Percentage of total plant derived nutrient mass stored in crop tree stembark and stemwood for pools for 19-year-old stands of Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) on sites located in the central Coast Range (CR) and the Cascade foothills (CF) of western Oregon. Stands were grown under contrasting vegetation management treatments: Control, no post-planting vegetation management (C), and 5-years of post-planting vegetation management (VM).

Site	Species	Treatment	C	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Na	Zn
CR	DF	C	59.1	13.4	15.8	21.2	23.3	17.7	32.8	23.0	31.3	3.4	10.8	32.0	34.8
		VM	61.2	13.6	17.4	31.8	15.8	21.4	34.3	24.8	34.0	3.8	11.4	18.6	37.7
	WH	C	29.3	7.2	9.9	11.1	12.8	9.6	12.3	14.7	17.1	3.6	13.3	8.6	16.0
		VM	65.3	25.6	25.2	30.3	31.8	28.7	47.1	28.7	45.2	8.4	28.1	22.1	39.9
	WRC	C	7.9	2.2	2.0	2.4	6.6	2.7	2.9	5.3	4.1	0.6	2.2	2.1	5.8
		VM	41.7	10.3	9.3	13.4	24.4	16.4	27.0	24.3	21.7	6.3	6.2	9.5	21.5
	GF	C	29.9	10.0	9.3	13.2	14.7	10.2	11.3	16.1	20.2	3.1	13.7	8.4	21.4
		VM	67.0	20.8	15.8	20.2	22.3	27.0	45.5	31.7	38.9	13.7	20.7	14.2	28.2
CF	DF	C	50.6	18.2	14.0	14.8	14.7	12.4	24.6	18.1	31.8	4.6	13.4	8.8	35.3
		VM	59.8	19.3	15.8	22.0	15.4	18.4	36.0	21.1	46.5	6.7	11.3	15.3	41.9
	WRC	C	23.3	12.5	4.5	3.6	8.4	5.3	11.6	7.2	9.9	1.0	1.4	1.8	6.6
		VM	38.3	24.6	8.9	9.6	11.7	12.5	23.0	16.3	17.7	2.2	2.5	4.4	15.3



Appendix Fig. A1. Average boron (B) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the Control and VM treatments for a given site and species.

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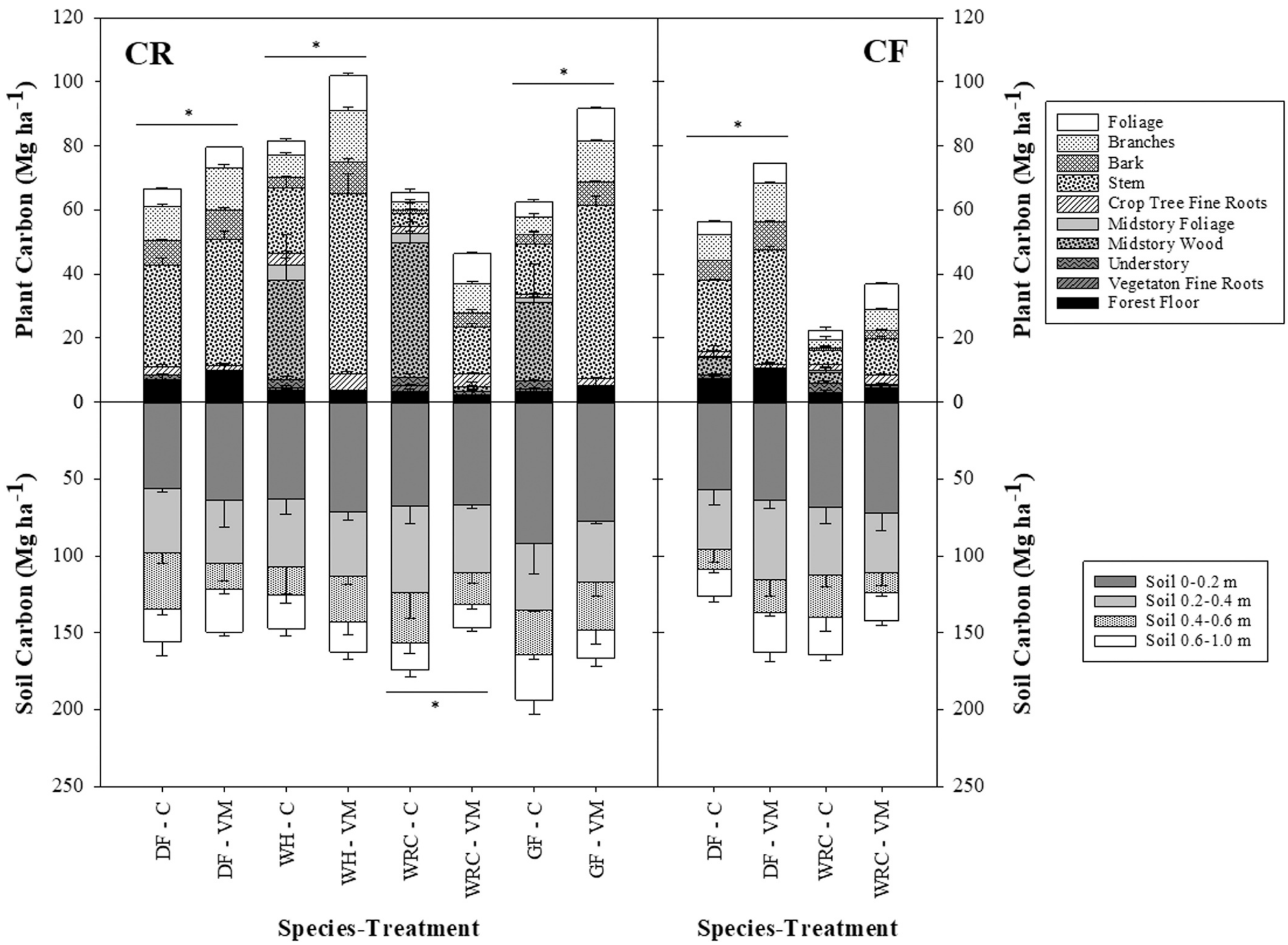

Appendix Fig. A2. Average carbon (C) stocks (Mg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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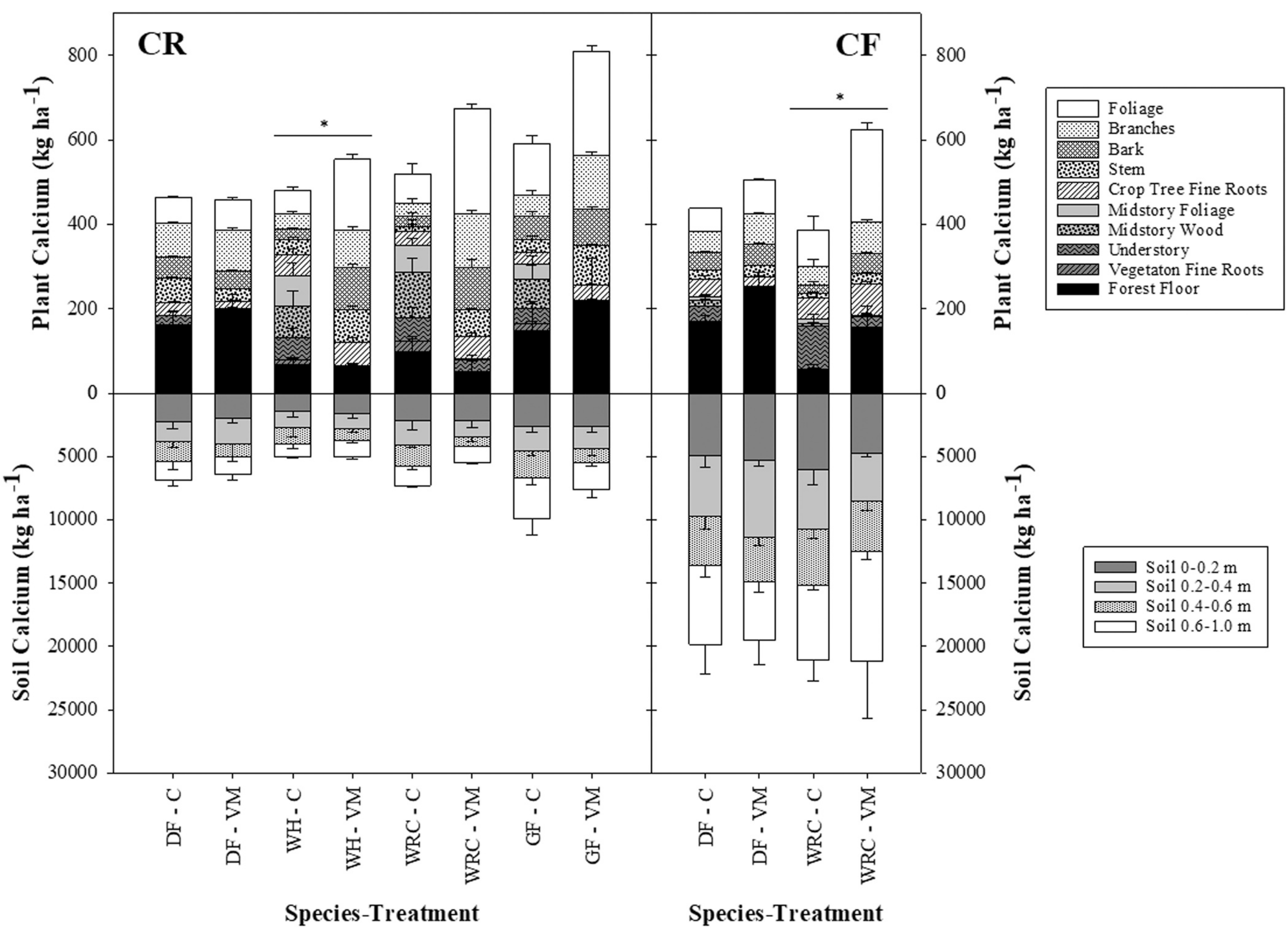

Appendix Fig. A3. Average calcium (Ca) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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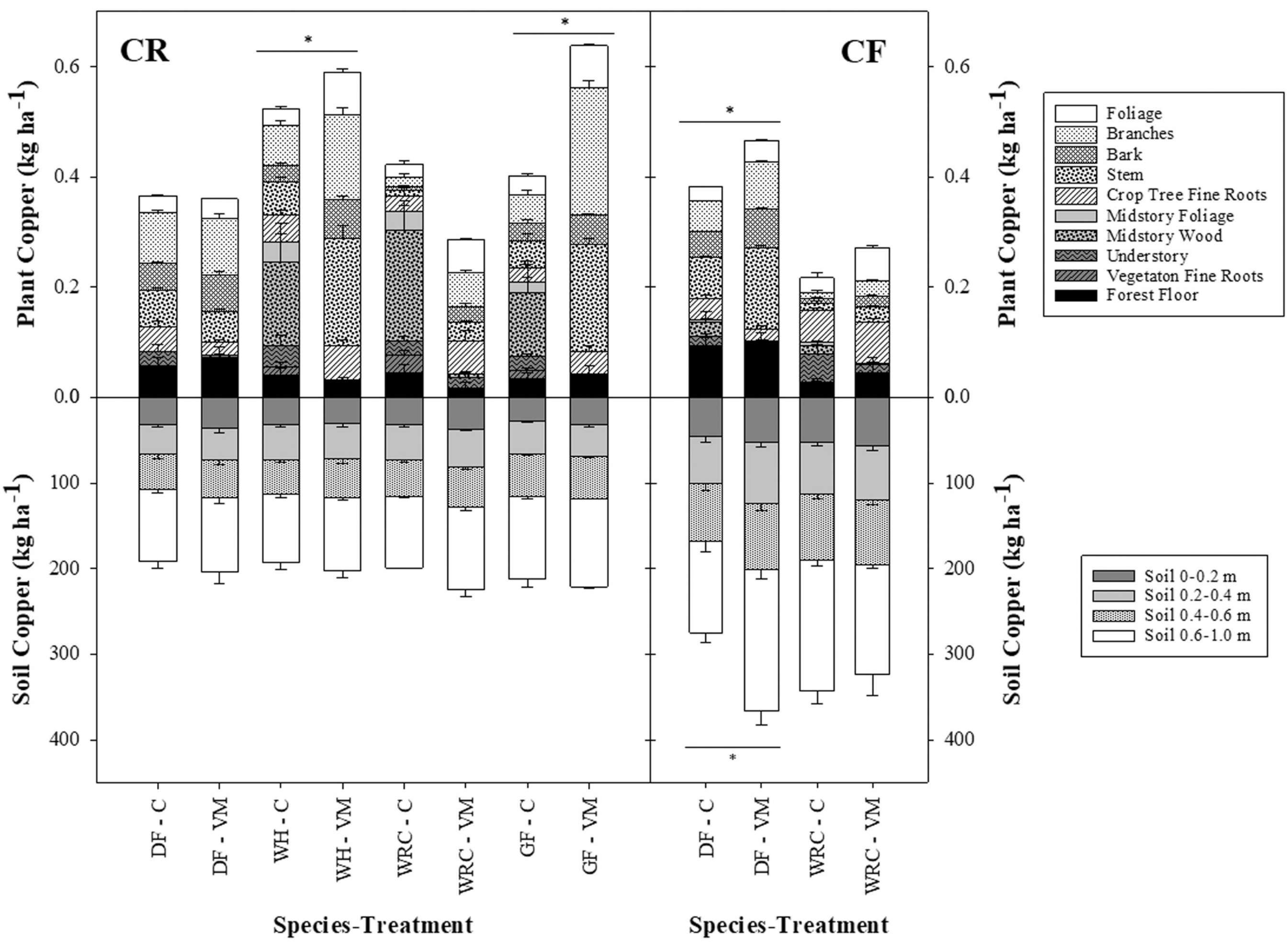

Appendix Fig. A4. Average copper (Cu) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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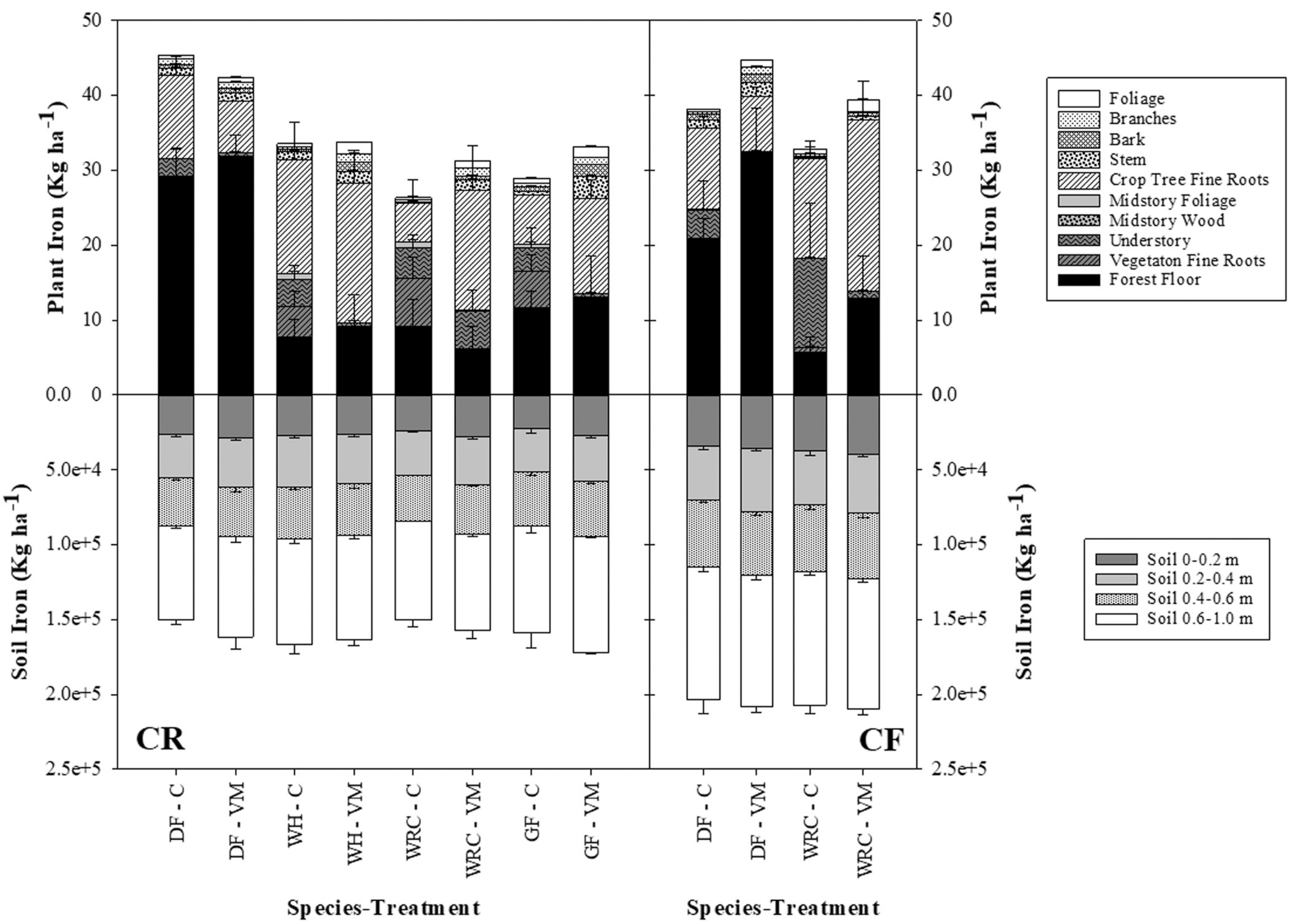

Appendix Fig. A5. Average iron (Fe) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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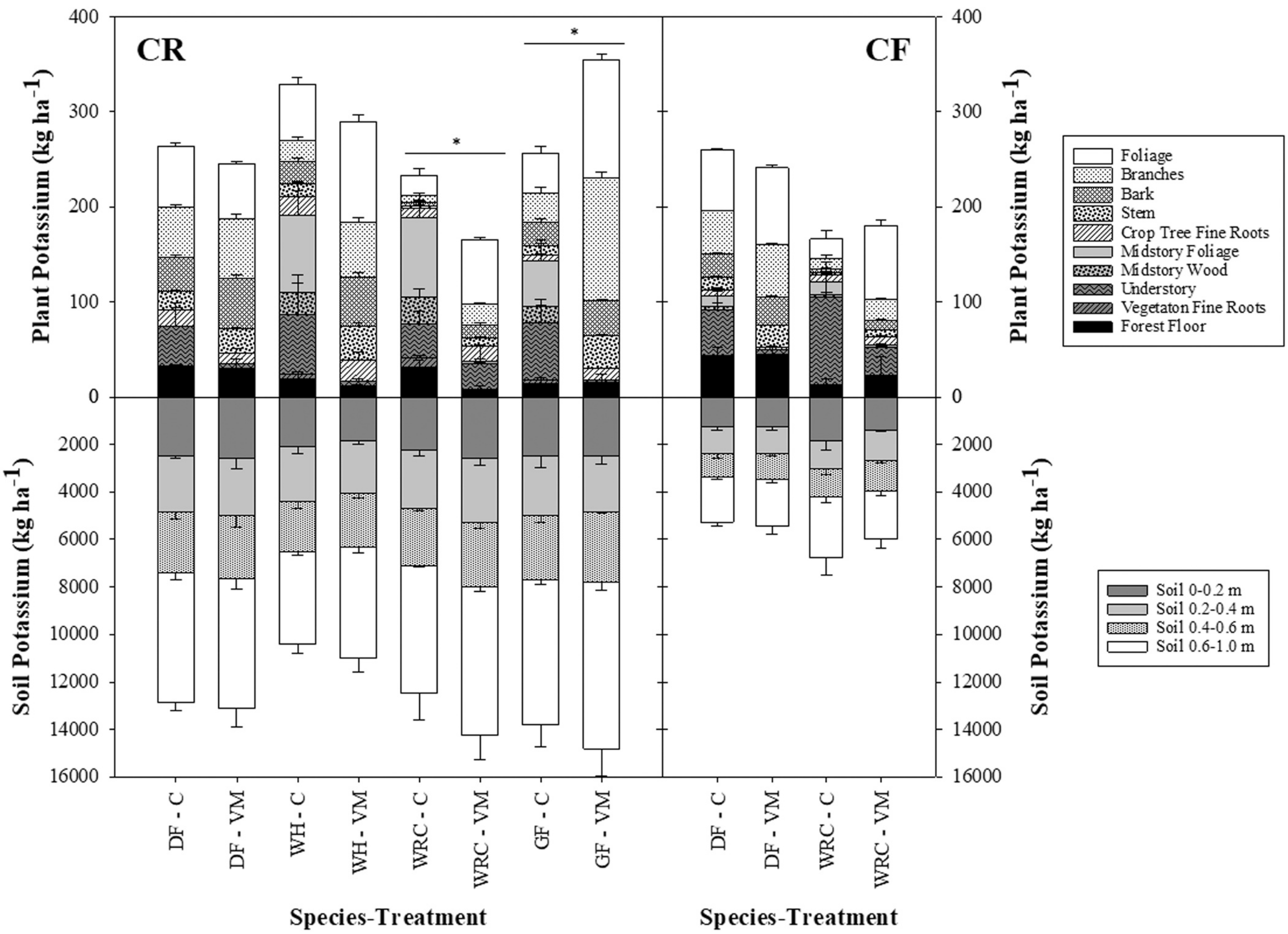

Appendix Fig. A6. Average potassium (K) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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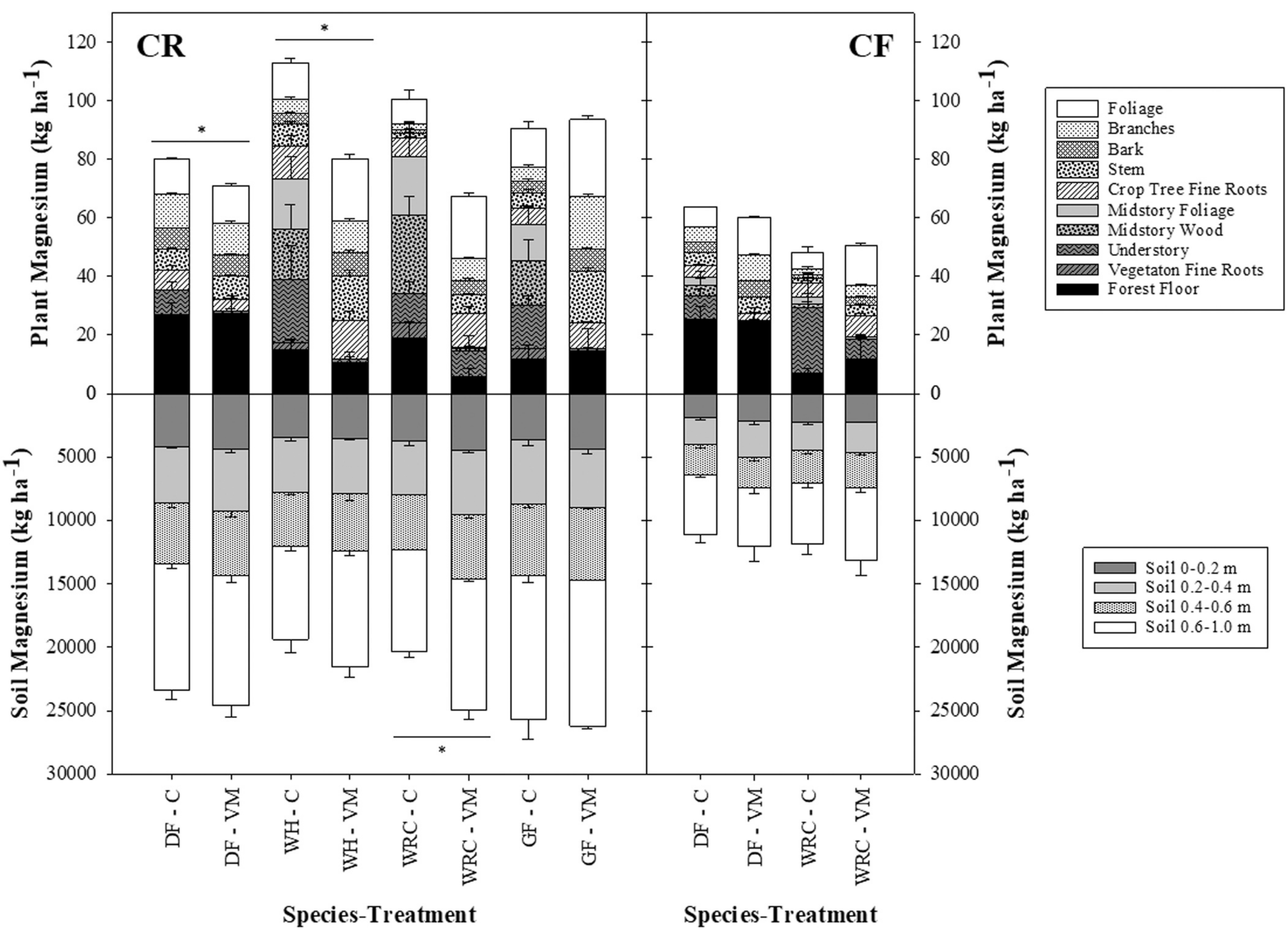

Appendix Fig. A7. Average magnesium (Mg) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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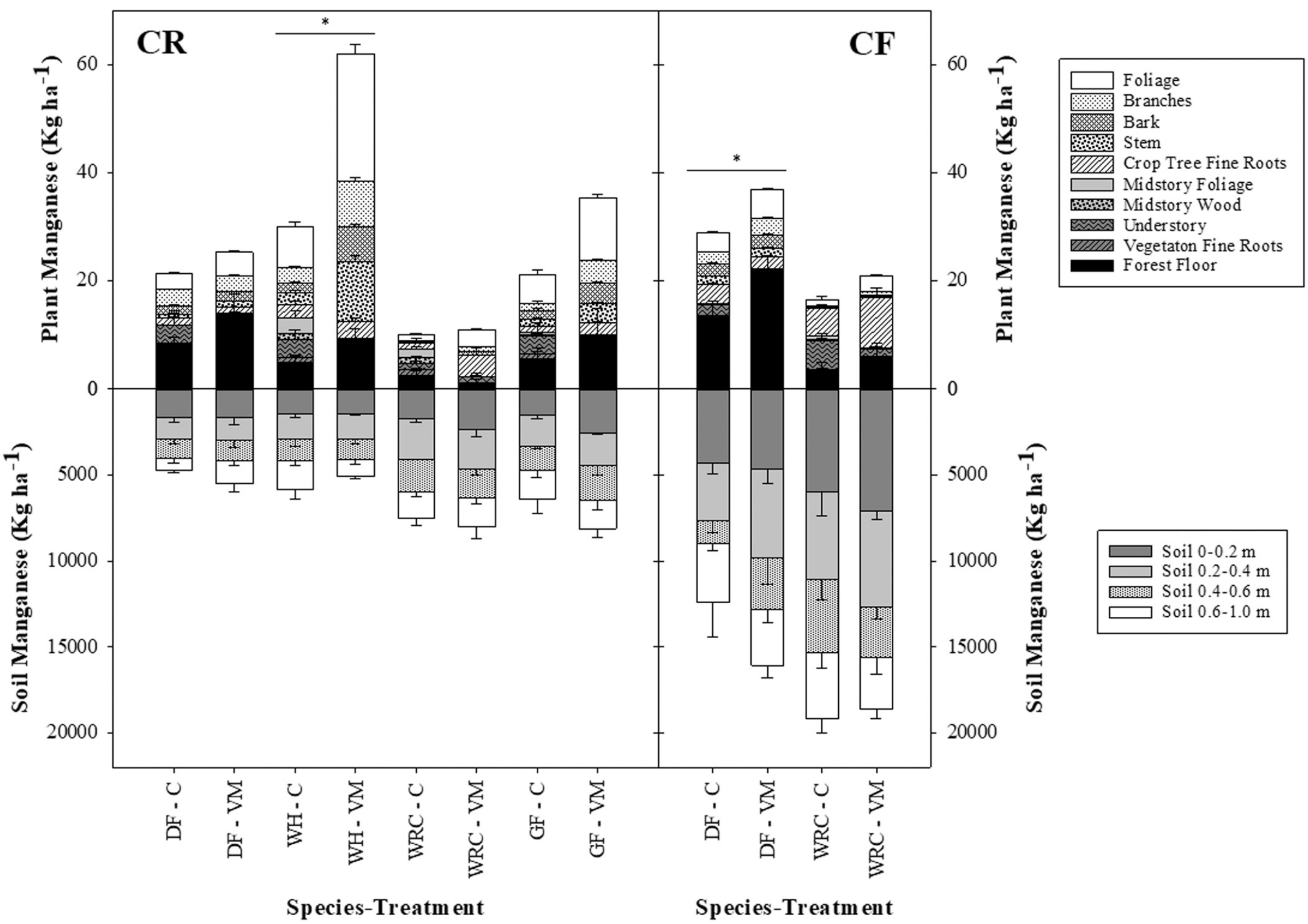

Appendix Fig. A8. Average manganese (Mn) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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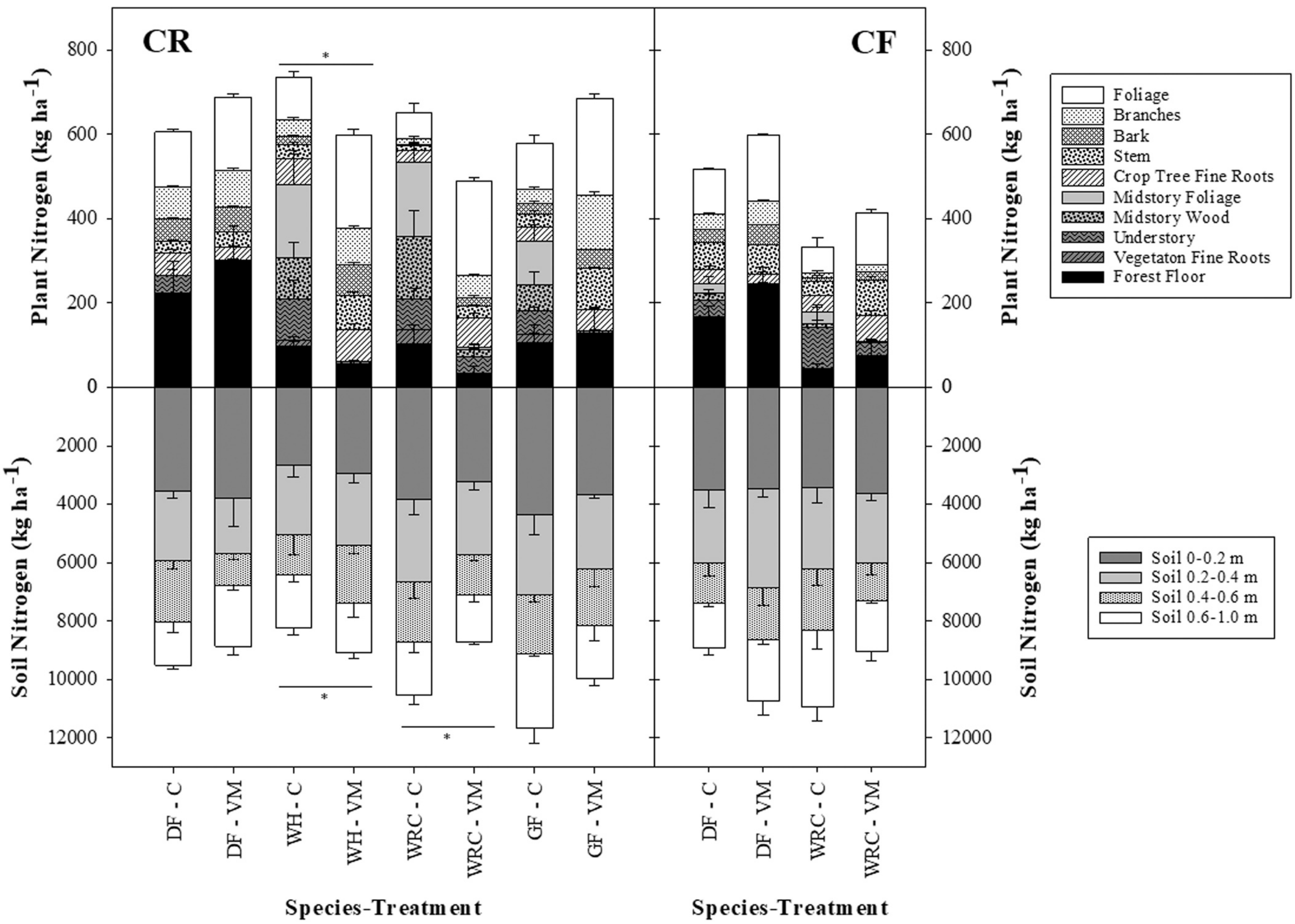

Appendix Fig. A9. Average nitrogen (N) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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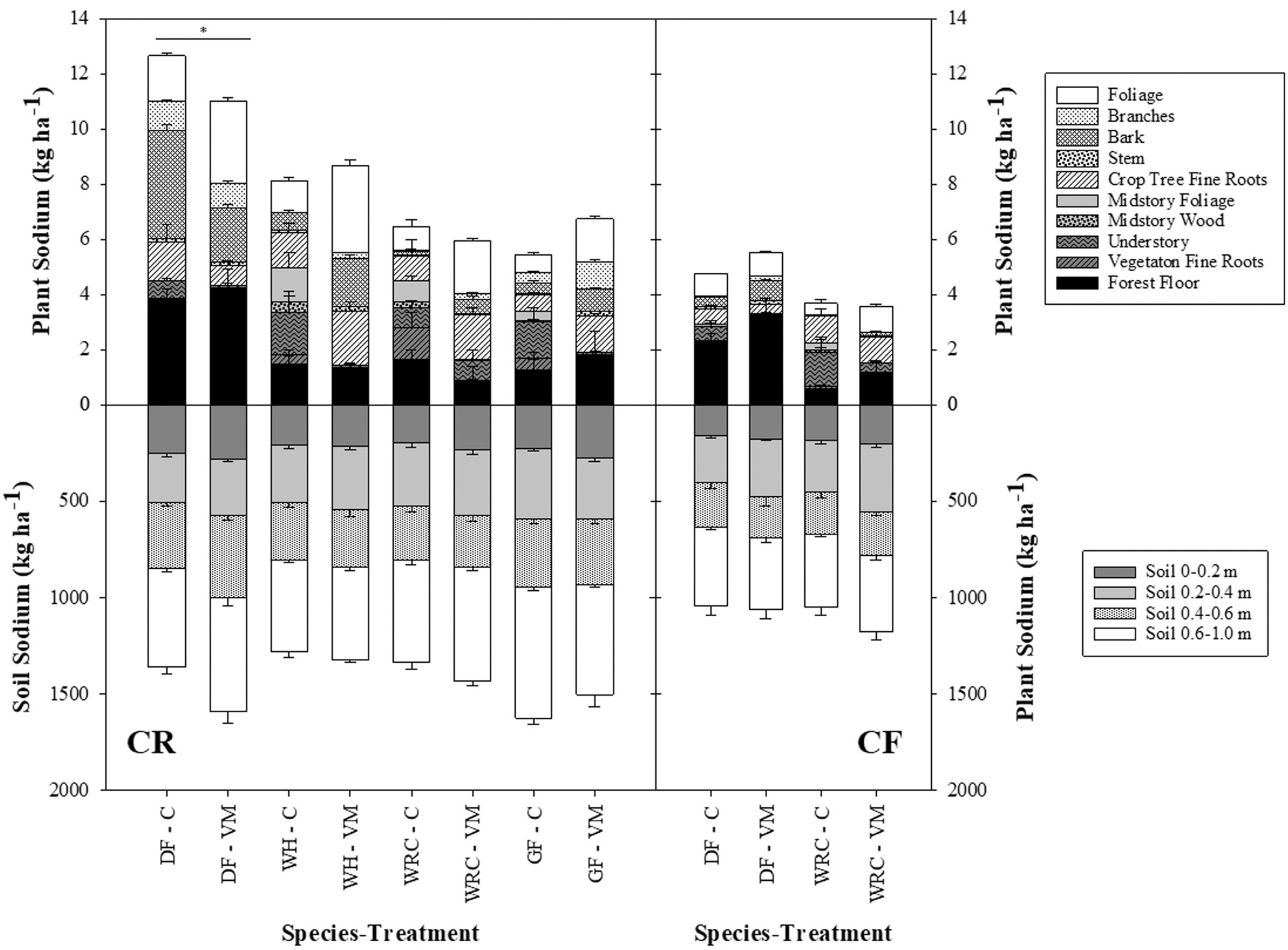

Appendix Fig. A10. Average sodium (Na) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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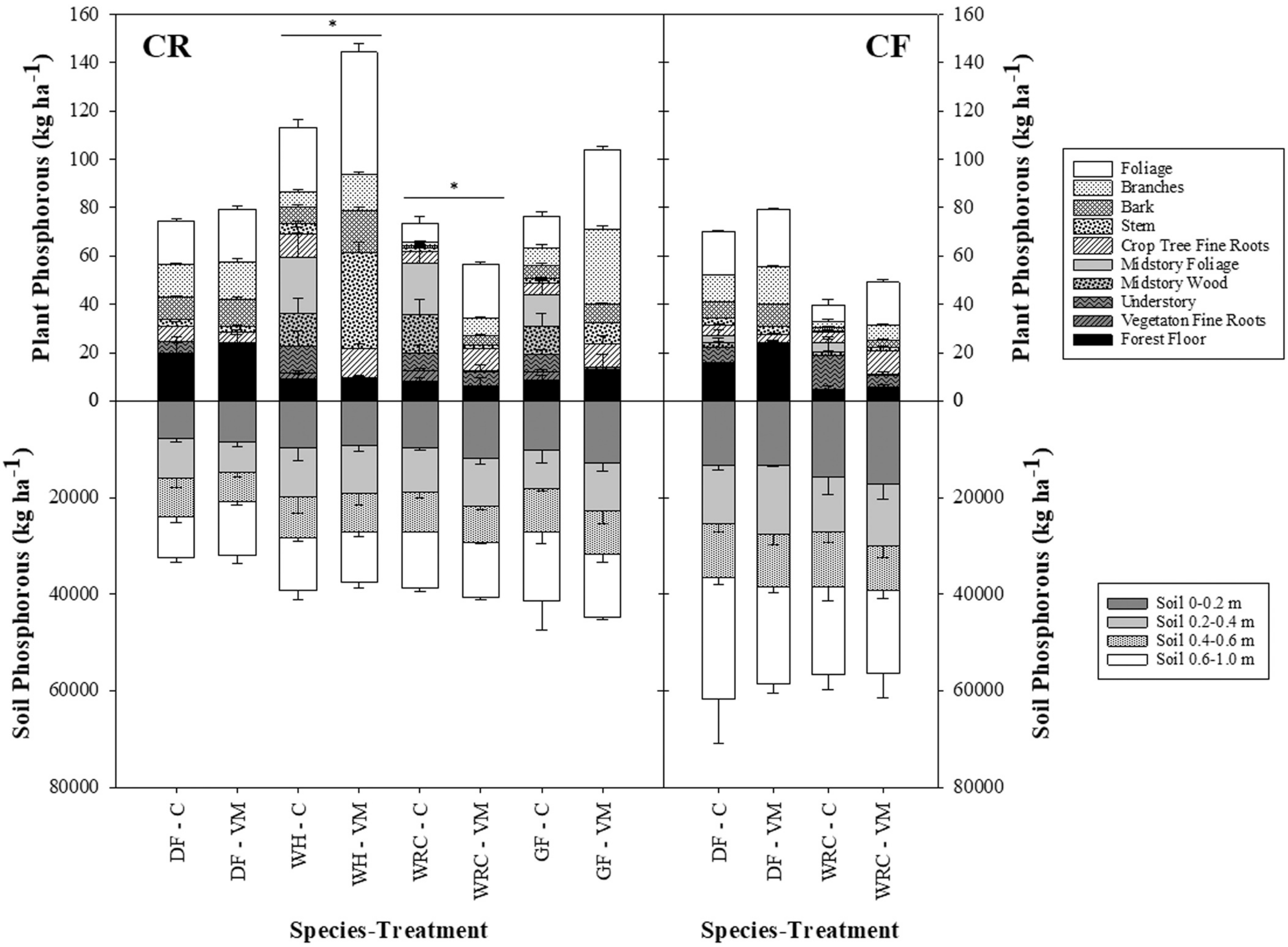

Appendix Fig. A11. Average phosphorous (P) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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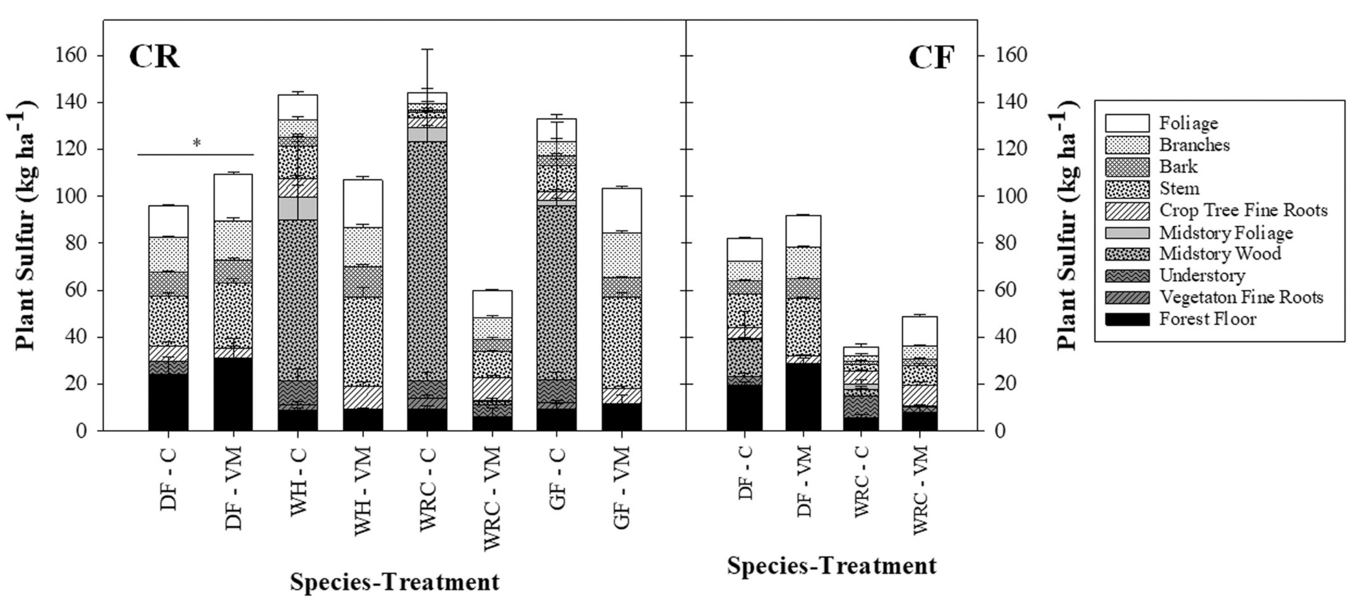
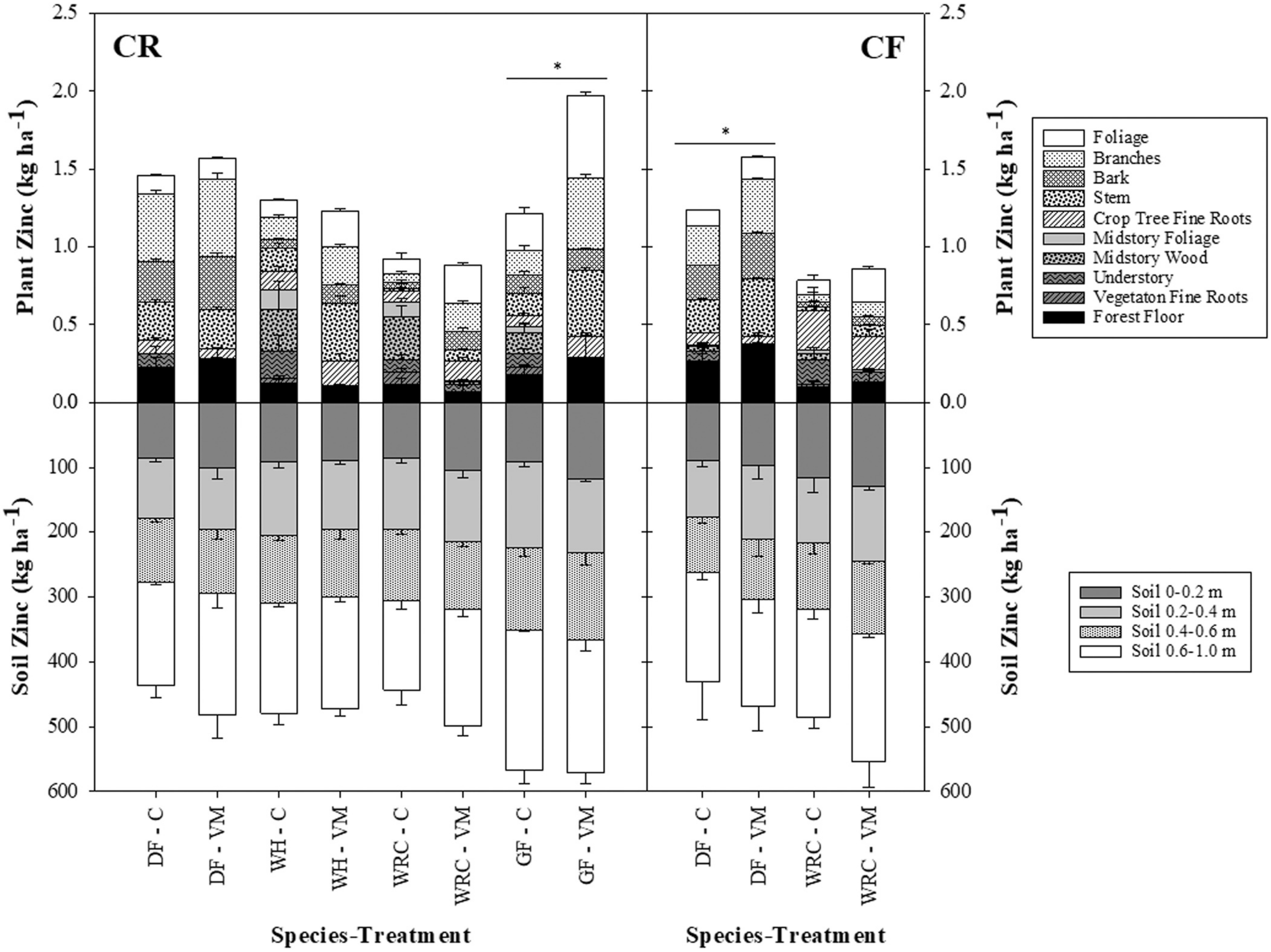


Appendix Fig. A12. Average Sulfur (S) stocks (kg ha^{-1}) of plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species..



Appendix Fig. A13. Average zinc (Zn) stocks (kg ha^{-1}) of soil and plant derived nutrient pools for 19-year-old Douglas-fir (DF), western hemlock (WH), western redcedar (WRC), and grand fir (GF) stands growing under contrasting vegetation management treatments (no post-planting vegetation management, C, and 5-years of post-planting vegetation management, VM) on sites located in the central Coast Range (CR) and Cascade Foothills (CF) of western Oregon. Error bar represent standard error. An * indicates significant differences between the C and VM treatments for a given site and species.

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