Plant biomass and nutrient stores in seven small watersheds at the H.J. Andrews Experimental Forest: A preliminary report

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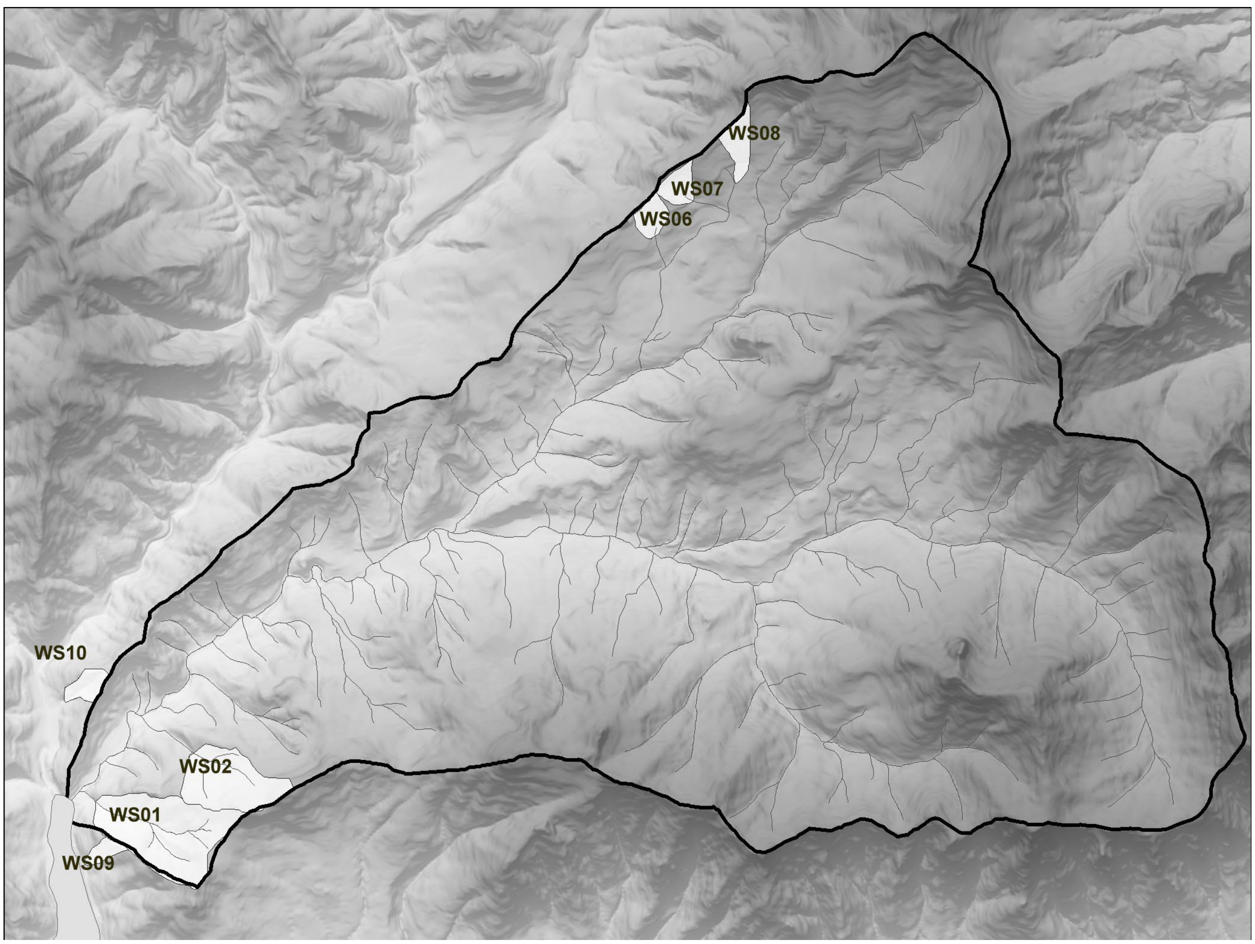


TABLE OF CONTENTS

Introduction

Understanding the long-term dynamics of forest plant biomass and their associated stores of carbon (C), nitrogen (N), and other plant nutrients is critical for predicting their future role in the global C cycle, N cycle, and soil fertility processes. Much research has been performed at the H.J. Andrews Experimental Forest (HJA) to document live plant biomass on a stand level (Acker et al. 1998, Acker et al. 2002, Halpern 1988, Halpern 1989, Halpern & Franklin 1990, Halpern & Spies 1995). While stand level data is important, it may not accurately represent a watershed as a whole, and therefore its use is limited when the goal is to scale information to the watershed or landscape level. Small watersheds, on the other hand, are large enough to represent integrated landscape units, yet small enough to directly measure. This ability to scale information to the landscape level will aid in testing and developing new conceptual and simulation models of forest nutrient cycling and will ultimately help to identity the minimum patch size needed to represent the larger ecosystem. Furthermore, one of the central guiding questions of the HJA LTER (long-term ecological research) program is: How does land use affect carbon and nutrient dynamics? New estimates of nutrient stores can be compared across watersheds dominated by young- versus old-growth forests to help understand nutrient dynamics in small watersheds over successional time and between different forest management strategies. Our new estimates of nutrient stores can also be compared to previously measured nutrient stores (Sollins et al. 1980), to help us understand nutrient dynamics in small watersheds under a regime of climate change.

This preliminary report focuses on seven small watersheds at the HJA as part of the LTER5 proposal to understand the current stores and successional dynamics that were measured of C, N, and other nutrients in forest ecosystems of the Pacific Northwest. Small watersheds (i.e., headwater basins with 1st-order channels) represent over 80% of the total area of the HJA.

Ground based inventories of forest plant biomass and nutrient stores represent the most direct way of documenting these components of a forested watershed. The intent of the ground based measurements made for this study was to provide bulk biomass and nutrient data for use in general estimates of long-term stores of plant nutrients within multiple small watersheds. Field measurements focused on the aboveground portion of live and dead plant biomass including trees, shrubs, herbs, logs, snags, stumps, fine woody debris, and forest floor material.

Biomass measurements of each live and dead plant component were performed in pre-existing fixed area plots along transects that captured most of the variation within each of the seven watersheds. Samples of live plant material were collected in each watershed and nutrient content was measured for each component (trees, shrubs, and herbs). Live trees constitute the majority of biomass within a forested watershed and therefore additional nutrient analysis was performed for the dominant species by collecting individual substrate samples (bark, wood, foliage, and new foliage) to more precisely determine nutrient stores within live trees. Forest floor material and fine woody debris samples were collected for nutrient analysis. Previously existing nutrient content data was utilized for logs, snags, and stumps (Harmon and Sexton 1996).

Study Area

Physical environment

The Andrews Forest is situated in the western Cascade Range of Oregon in the 15,800-acre (6400-ha) drainage basin of Lookout Creek, a tributary of Blue River and the McKenzie River. Elevation ranges from 1350 feet (410 m) to 5340 feet (1630 m). Broadly representative of the rugged mountainous landscape of the Pacific Northwest, the Andrews Forest contains excellent examples of the region's conifer forests and associated wildlife and stream ecosystems (http://www.fsl.orst.edu/lter/about.cfm?topnav=2).

The maritime climate has wet, mild winters and dry, cool summers. At the primary meteorological station near headquarters at 1400 feet (430 m) elevation, mean monthly temperature ranges from near 34 degrees F (1 degree C) in January to 64degrees F (18 degrees C) in July. Average annual precipitation varies with elevation from about 91 inches (230 cm) at the base to over 140 inches (355 cm) at upper elevations, falling mainly in November through March. Rain predominates at low elevations; snow is more common at higher elevations. Highest stream flow occurs generally in November through February during warm-rain-on-snow events.

Small watershed management histories

Watershed 1 (WS01) was 100% clearcut over a four-year period from the fall of 1962 to the summer or 1966. Skyline yarding was used to remove timber from the entire 237 acres and no roads were constructed in the watershed. Debris burning in October 1966 consumed most of the fine logging debris on the slopes and in the stream channel.

Watershed 2 (WS02) is an uncut control for WS01. The forest represents a mix of old-growth and mature trees.

Watershed 6 (WS06) was 100% clearcut in 1974. Logs in 90% of the watershed were yarded uphill by a high-lead cable system; logs in the remaining 10% were yarded by tractor. Logging residue was broadcast burned in the spring of 1975, and the watershed was planted with Douglas-fir seedlings in the spring of 1976. A road (still present and maintained) was constructed through the watershed.

Watershed 7 (WS07) was shelterwood cut in 1974 with approximately 60% of basal area removed and 30 to 40 trees per acre left as overstory. The watershed was tractor logged above the road and cable logged below the road. In 1975 a broadcast burn was made just below the road. In 1976 the District planted all of WS07. In 1984 the rest of the overstory canopy was removed. In 2001 WS07 was thinned to about 220 trees per acre.

Watershed 8 (WS08) is an uncut control for WS06 and WS07. No significant difference was found among WS06, 07, and 08 pre-treatment basal area. The forest represents a mix of old-growth and mature trees.

Watershed 9 (WS09) is an uncut control for WS10. The forest represents a mix of old-growth and mature trees.

Watershed 10 (WS10) was 100% clearcut in 1975. Clearcutting occurred during the spring and summer, and a running skyline system yarded all logs and unmerchantable material >20 cm in diameter or >2.4 meters in length uphill to a single landing. WS10 was not burned.

Table 1. Summary of small watershed metric's and history

Stand	Elevation (m)	Slope (%)	Aspect (degrees)	Stand age	Plot Count	History
WS01	460-990	59	286	41	40	Clearcut 1962-1966 Debris burned 1966
WS02	530-1070	59	289	Mixed	Varies	Uncut control >450 years old Mixed ages
WS06	880-1010	25	165	30	22	Clearcut 1974 Burned 1975 Planted 1976
WS07	910-1020	34	158	30	24	Shelterwood 60% 1974 Burned 1975 Planted 1976 Large trees removed 1984 Thinned 220 t/ac 2001
WS08	960-1130	26	165	Mixed	22	Uncut control 33% 450+ years old 67% <125 years old
WS09	425-700	58	247	Mixed	15	Uncut control >250 years old Mixed ages
WS10	425-700	58	250	30	20	Clearcut 1975

Methods

Biomass determination

Live tree biomass

Each of the watersheds in this study contains permanently established circular, fixed area plots (0.1 ha) along transects with multiple tree measurements over time. The most recent date of tree measurement was determined for each watershed and that data was utilized in this study. Total mean biomass per hectare for WS06, 07, 08, and 09 had already been calculated using a program written by Gody Spycher (Howard Bruner, personal communication). For WS01 and WS10 individual tree biomass data was located on the H.J. Andrews internet site http://www.fsl.orst.edu/lter/data / (data codes TP073 and TP041). Tree biomass was then summed within a plot, and then a mean value was determined for the watershed. For WS02 only tree re-measurement data for diameter at breast height was available (TV010). Allometric equations from the Pacific Northwest Plant Biomass Component Library (TP072, Means et al. 1994) were used to determine individual tree biomass from the diameter at breast height measurements. Subsequently, all individual tree biomass values were summed by plot, and then plot values were averaged over the watershed. If a plot had no trees, then it was assigned a value of zero for averaging. In all cases biomass was calculated on a slope-corrected area basis.

Understory plant biomass

Herbs: Percent cover was visually estimated for every herb species rooted in 2 x 2 m permanently staked plots within the 0.1 hectare tree plots (Franklin and Dyrness 1973, Halpern 1987). Some larger herb species also required a DBA (diameter at base) measurement. Total mean biomass per hectare for WS06, 07, 08, and 09 had already been calculated using a program written by Gody Spycher (Howard Bruner, personal communication). For WS01 and WS10 mean biomass by species on a plot was available (Charles Halpern, personal communication and TP041). This data was then summed within a plot and a mean of the plots was determined for the watershed. WS02 had percent cover data available (TP091). Individual plant biomass was then calculated using allometric equations from the Pacific Northwest Plant Biomass Component Library (TP072, Means et al. 1994). This data was then summed within a plot and a mean of the plots was determined for the watershed.

Shrubs: Diameter at base measurements were taken for all shrub species and trees < 5 cm DBH rooted within the same 2 x 2 m plots as the herb measurements (Franklin and Dyrness 1973, Halpern 1987). In addition, either the modal height (the most common height in the plot), or the individual height of a stem were recorded. Total mean biomass per hectare for WS06, 07, 08, and 09 had already been calculated using a program written by Gody Spycher (Howard Bruner, personal communication). For WS01 and WS10 mean biomass by species on a plot was available (Charles Halpern, personal communication, and TP041). This data was then summed within a plot and a mean of the plots was determined for the watershed. WS02 had percent cover data available (TP091). Individual plant biomass was then calculated using allometric equations from the Pacific Northwest Plant Biomass Component Library (TP072, Means et al. 1994). This data was then summed within a plot and a mean of the plots was determined for the watershed.

Coarse woody debris (CWD) biomass

Coarse woody debris is defined as woody detritus with a diameter of 10 cm or greater. For this study CWD was measured using two methods:

Logs: For downed coarse woody debris the line intercept method was used to determine the volume logs within a plot (Harmon and Sexton 1996). At each plot logs were measured along four 25 m long transects in cardinal directions originating from the center of the live tree plots. For each log encountered the species, decay class, and diameter at line intercept were recorded. Biomass was then determined by multiplying the log volume by a species and decay class specific density. If species specific density was not available for a decay class than substitution of a similar species was utilized. The exception to this method was WS02 where field measurements were completed in 1982 by mapping every log in the plot and recording diameter and length, which was then used to determine volume.

Snags and stumps: All standing dead trees (snags) and cut tree stumps were measured in the 0.1 ha permanent tree plots. Species, decay class, diameter, and height were recorded and used to determine volume. Biomass was then determined by multiplying the volume by a species and decay class specific density. If species specific density was not available for a decay class than substitution of a similar species was utilized. The exception to this method was WS02 where field measurements were completed in 1982 by mapping every snag in the plot and recording diameter and height, which was then used to determine volume.

Fine woody debris biomass

For this study fine woody debris (FWD) was defined as any piece of woody material with a diameter at midpoint greater than 0.5 cm but less than 10 cm. The line intercept method was used to determine the volume of FWD within a plot (Harmon and Sexton 1996). At each plot FWD was tallied along four 4 m long transects in cardinal directions originating from the center of the live tree plots. Each FWD piece was categorized into one of two diameter classes (0.5-2.4 cm or 2.5-9.9 cm). To determine the average density of FWD within a size class, approximately 30 pieces of FWD from each class were collected from WS06, 07, 08, 09, and10. Density was determined by using the diameter, length, and oven dry weight of each piece of FWD. The mean density was then calculated by size class within each watershed. Total biomass was then determined by multiplying the size specific density by the volume for each size class within each watershed. For WS02, where no measurements were made, we used the average of the two comparable control stands (WS08 and 09).

Forest floor litter biomass

For this study, forest floor was defined as organic matter < 0.5 cm diameter down to mineral soil. Using a corer, four samples were collected along one of the FWD 4 m transects at one meter intervals. If the core contained rotten wood this material was separated and weighed individually. All four samples were pooled for each plot and a mass per unit area was determined. A mean biomass per area was then derived from an average of all plots.

Nutrient content determination

Physical sampling

The sampling for nutrients for each category was as follows:

1) Forest floor nutrient content was determined from cores collected on each vegetation plot within each watershed. In each plot 4 cores were collected along a transect. Each core sample was then separated into two components: very rotten wood and other material. All samples were then pooled based on component.
2) Fine woody debris pieces were collected by size class within each plot to determine average density and total nutrient content.
3) Trees were sampled adjacent to vegetation plots. The range of species and sizes were selected to represent the distribution observed in the plots, with sampling using a stratified random design so that sample trees represented a wide diameter range. At least 10 trees of dominant species and 5 trees of subordinate species were sampled. Samples of foliage, twigs, branches, bark, sapwood, and heartwood were taken from each tree. Foliage and branches were taken at multiple heights using clippers where possible and a shotgun when necessary. Bark was removed using a cork cutter or chisel. Wood was sampled using an increment corer.
4) Shrubs were sampled in two forms: large shrubs and small shrubs that are usually inventoried with herbs. Both had foliage and woody tissues collected from plants rooted near vegetation sample plots. These samples were taken from a range of species at the site, with the intent of getting a reasonable average. Samples were pooled within a watershed based on shrub size.
5) Herbs were sampled similarly to shrubs, with multiple species and life-forms being mixed together to get a reasonable average value across a watershed.
6) Logs, snags, and stumps did not have physical samples collected because nutrient data existed for these components from previous studies (e.g., Sollins et al. 1987).

Chemical analysis was performed at Central Analytical Laboratory located on the Oregon State University campus. Carbon and nitrogen content was determined using a Leco CNS-2000 Macro Analyzer. Cations and phosphorus were determined using a Perkin Elmer Optima 3000DV inductively-coupled plasma optical emission spectrometer with a diode array detector.

Determination of plant tissue proportions for biomass and nutrients

Live trees constitute the majority of biomass in forested watersheds at the HJA and their individual tissues store nutrients in different proportions. Therefore, further analysis was performed to provide more detail into the allocation of biomass within the bark, wood, and foliage of live trees to facilitate more accurate determination of overall nutrient stores (appendix 6). Allometric equations from the Pacific Northwest Plant Biomass Component Library (TP072, Means et al. 1994) were used to determine percent of biomass in foliage, bole bark, bole wood, and branches for each species sampled (TP07210) based on diameter at breast height. If allometric equations did not exist for specific tree species, then substitutions were used based on growth form. An average of all hardwoods by age class was used as substitution for *Arbutus menziesii*, *Cornus nuttallii*, *Prunus emarginata*, and *Rhamnus purshiana*. The equation for *Thuja plicata was* used for *Calocedrus decurrens* and *Abies procera* used for *Abies grandis*. For *Taxus brevifolia* an average of all softwoods by age class was utilized. A ratio of bole bark to bole wood was then calculated and used to estimate the ratio of branch bark to branch wood in order to separate these two tissues. Bole and branch bark and wood, respectively, were added together to create total bark and total wood. Nutrient contents were determined for each individual tree tissue (bark, wood, and foliage) and then summed for the total value. When nutrient values were not available for a specific species, then a mean of all values for that nutrient was used.

For logs, snags, and stumps, previously existing data of tissue proportions (bark and wood) based on decay class (Harmon, unpublished) was used for to determine the average percent of bark remaining (appendix 5). If data did not exist for specific species, then substitutions were used based on growth form, similar to the live trees. Nutrient content for bark and wood was determined separately and then summed for the total.

Forest floor samples were separated into litter and rotten wood components. For the portion that was rotten wood nutrient values were used for decay class 5 *Pseudotsuga menziesii*.

Understory plants and fine woody debris pieces were not separated by tissue; nutrient analysis was performed on a whole plant/piece basis.

Results: biomass and nutrient stores

The amount of biomass and nutrients stored in cut versus uncut watersheds is significantly different. For this reason the results from cut and uncut stands are presented separately for biomass and each nutrient component. Furthermore, the total values for logs, snags, and stumps remain separated when presenting the larger pools of biomass and carbon, but have been combined into a coarse woody debris category (CWD) for the presentation of the smaller pools of nutrient contents.

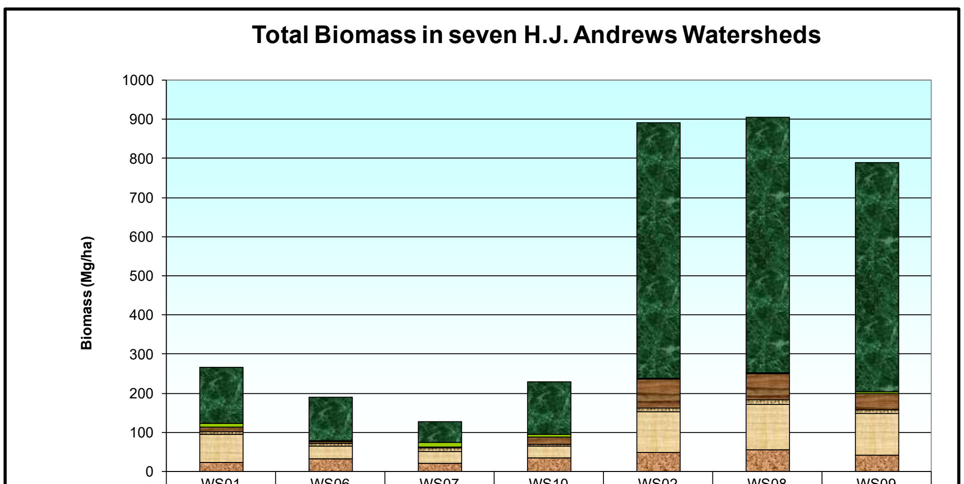
Biomass in control stands

Total biomass was found to be highest in the control stands (WS02, 08, 09) with total biomass values ranging from 790 to 906 Mg/ha. Within these stands live trees dominate the biomass with values ranging from 585 to 654 Mg/ha, or an average of 73% of the total biomass aboveground. Wood is the largest component of the live tree biomass accounting for on average 78% of the total live tree biomass, with bark at 14% and foliage at 7%. The next largest component in these stands is logs with biomass values ranging from 103 to 115 Mg/ha or an average of 12% of the total biomass. Again, wood is the largest component with an average of 91% of the total log biomass across all decay classes and bark makes up 9% of the log biomass. Snags and stumps also make up a sizeable portion of the aboveground biomass in the older stands with values ranging from 42 to 75 Mg/ha or 7% of the total biomass on average. The forest floor comprised 6% of the total biomass with values between 43 and 57 Mg/ha. Fine woody debris stored 8 to 11 Mg/ha or 1% of the total biomass. Understory plants comprised on average only 0.34% of the total biomass with values ranging from 2 to 5 Mg/ha.

<u>Biomass in cut stands</u>

The younger watersheds have less biomass than the associated control watersheds. For example, with a total biomass of 231 Mg/ha, WS10 contains only 29% of the total biomass of WS09. The total biomass values for the cut stands ranged from 130 to 231 Mg/ha. Live trees comprise the majority of the biomass with an average 53% of the total. As in the uncut stands, logs are the next largest component of total biomass except in WS06 and WS10, where the forest floor had slightly more biomass than the logs. When logs, snags, and stumps are combined coarse woody debris is the next largest component for these stands with values ranging from 32 to 84 Mg/ha, or an average 24% of the total biomass. When compared with the control stands, the managed stands had a larger proportion of forest floor material ranging from 9 to 18 Mg/ha or 15% of the total. Biomass values for fine woody debris ranged from 3 to 7 Mg/ha, representing an average 4% of the total. Similarly, herbs and shrubs had biomass values ranging from 2 to 7 Mg/ha or 4% of the total on average.

Figure 1. Total biomass in seven small watersheds by component



	WS01	WS06	WS07	WS10	WS02	WS08	WS09
Total biomass	267.41	190.89	130.08	231.52	893.86	906.36	790.95
Live tree	142.28	109.70	55.20	134.32	654.03	652.20	585.00
Understory	8.89	4.07	9.96	8.23	1.99	1.97	4.62
Snag/Stump	12.65	3.40	3.36	16.81	74.60	68.57	42.07
Fine Woody Debris	7.14	6.42	9.77	6.39	9.73	10.99	8.47
Logs	72.18	32.82	28.75	29.00	103.31	115.21	107.79
Forest Floor	24.26	34.48	23.04	36.75	50.20	57.41	43.00

Table 2. Percent aboveground biomass stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	53.21	3.32	4.73	3.64	26.99	9.07
WS06	57.47	2.13	1.78	3.36	17.19	18.06
WS07	42.43	7.66	2.58	7.51	22.10	17.71
WS10	58.02	3.55	7.26	2.76	12.53	15.87
WS02	73.17	0.22	8.35	1.09	11.56	5.62
WS08	71.96	0.22	7.57	1.21	12.71	6.33
WS09	73.96	0.58	5.32	1.07	13.63	5.44

Carbon stores in control stands

Total carbon was highest in the un-cut control stands with total values ranging from 385 to 439 Mg/ha. Carbon stores closely follow the pattern of biomass stores with live trees containing the majority of carbon, an average 73% of the total, with values ranging from 287 to 319 Mg/ha. The next largest pool of carbon stored is in logs with totals ranging from 51 to 58 Mg/ha, or an average 13% of the total carbon. Snags and stumps store between 22 to 36 Mg/ha of carbon, an average 7% of the total. Forest floor material is the next largest pool with values ranging from 17 to 25 Mg/ha, or 5% of the total on average. Fine woody debris stored an average 1% and understory plants 0.3% of total carbon.

Carbon stores in cut stands

Just as in biomass, the cut stands have less carbon stored than the older control stands. Live trees constitute the majority of carbon with values ranging from 26 to 76 Mg/ha, an average of only 55% of the total carbon as compared to 73% for the un-cut stands. Logs comprise the next largest pool of carbon with values ranging between 14 and 36 Mg/ha, or 20% of the total on average. Forest floor material contains the third largest store of carbon with values ranging from 9 to 15 Mg/ha, an average of 13% of the total. Snags and stumps store approximately 4% of the total carbon with values between 2 and 8 Mg/ha. Understory plants and fine woody debris each comprise 4% of the total carbon with understory values ranging from 2 to 4 Mg/ha and fine woody debris from 3 to 4 Mg/ha.

Figure 2. Carbon stores in seven small watersheds by component

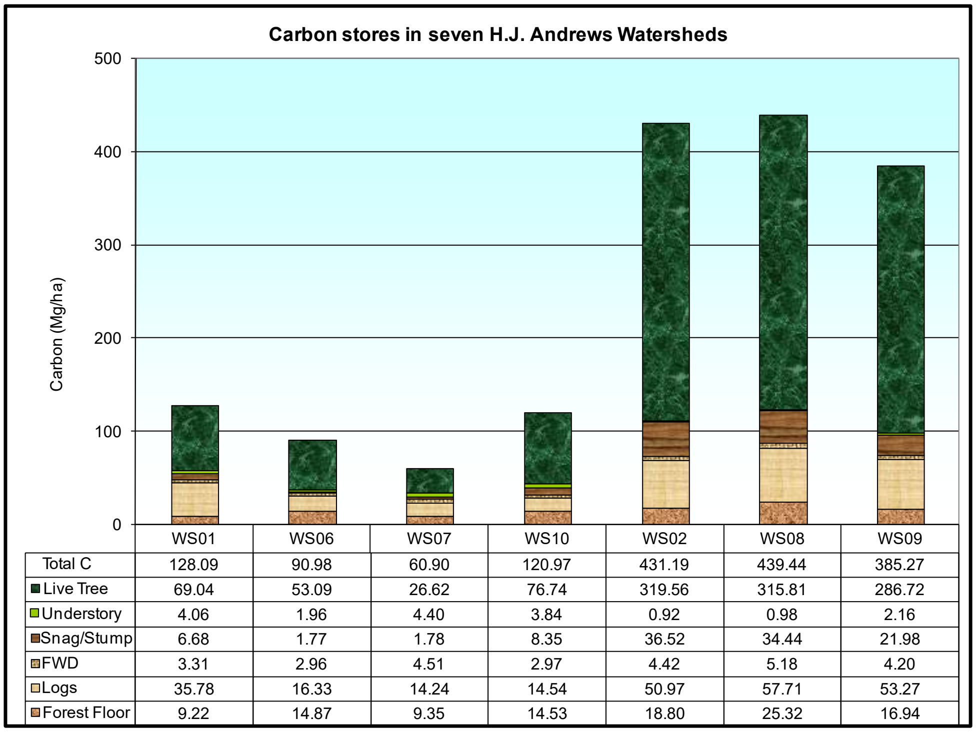


Table 3. Percent carbon stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	53.90	3.17	5.22	2.58	27.93	7.20
WS06	58.35	2.15	1.95	3.25	17.95	16.34
WS07	43.71	7.22	2.92	7.41	23.38	15.35
WS10	63.44	3.17	6.90	2.46	12.02	12.01
WS02	74.11	0.21	8.47	1.03	11.82	4.36
WS08	71.87	0.22	7.84	1.18	13.13	5.76
WS09	74.42	0.56	5.71	1.09	13.83	4.40

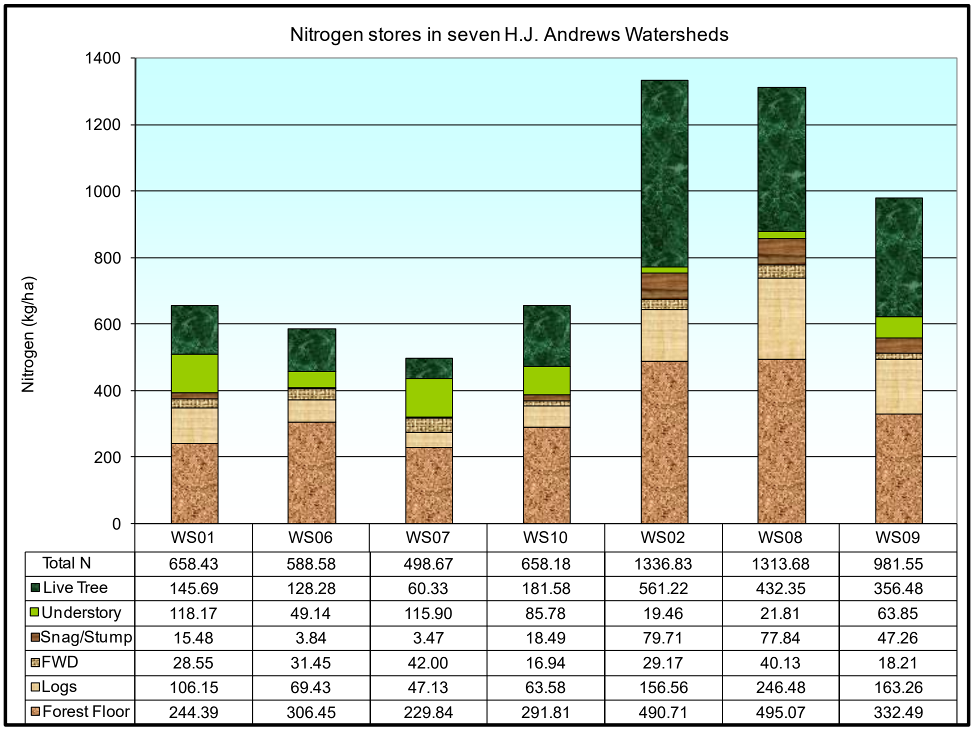
<u>Nitrogen stores in control stands</u>

As expected, given their higher biomass, the control stands had higher nitrogen values than the associated cut stands. Total nitrogen values for ranged from 982 to 1336 Kg/ha. Due to their dominant biomass, live trees contained the most nitrogen with values ranging from 356 to 561 Kg/ha, comprising an average 37% of the total nitrogen. However, the forest floor while comprising an average of only 15% of the total biomass, contained the next highest store of nitrogen with values ranging from 332 to 495 Kg/ha or an average of 36% of the total nitrogen. CWD contained a sizable portion of the nitrogen with values ranging from 210 to 324 Kg/ha or an average 21% of the total. Understory plants stored between 19 to 64 Mg/ha or an average of 4% of the total nitrogen. Fine woody debris contained between 18 and 40 Kg/ha of nitrogen or an average of 2% of the total.

<u>Nitrogen stores in cut stands</u>

While comprising an average 15% of the total biomass in the cut stands, the forest floor contained 230 to 306 Kg/ha or 45% of the total nitrogen, over twice the amount found in live trees which contained 60 to 181 Kg/ha or an average 21% to the total nitrogen. Also, while making up only 4% of the total biomass, the understory in cut stands contained 50 to 118 Kg/ha or on average 16% of the total nitrogen. CWD contained the next highest amount of nitrogen with values ranging from 50 to 121 Kg/ha or an average 13% of the total. Fine woody debris contained 17 to 42 Kg/ha or an average 5% of the total.

Figure 3. Nitrogen stores in seven small watersheds by component



	WS01	WS06	WS07	WS10	WS02	WS08	WS09
Total N	658.43	588.58	498.67	658.18	1336.83	1313.68	981.55
Live Tree	145.69	128.28	60.33	181.58	561.22	432.35	356.48
Understory	118.17	49.14	115.90	85.78	19.46	21.81	63.85
Snag/Stump	15.48	3.84	3.47	18.49	79.71	77.84	47.26
FWD	28.55	31.45	42.00	16.94	29.17	40.13	18.21
Logs	106.15	69.43	47.13	63.58	156.56	246.48	163.26
Forest Floor	244.39	306.45	229.84	291.81	490.71	495.07	332.49

Table 4. Percent nitrogen stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	22.13	17.95	2.35	4.34	16.12	37.12
WS06	21.79	8.35	0.65	5.34	11.80	52.07
WS07	12.10	23.24	0.70	8.42	9.45	46.09
WS10	27.59	13.03	2.81	2.57	9.66	44.34
WS02	41.98	1.46	5.96	2.18	11.71	36.71
WS08	32.91	1.66	5.93	3.05	18.76	37.69
WS09	36.32	6.51	4.81	1.86	16.63	33.87

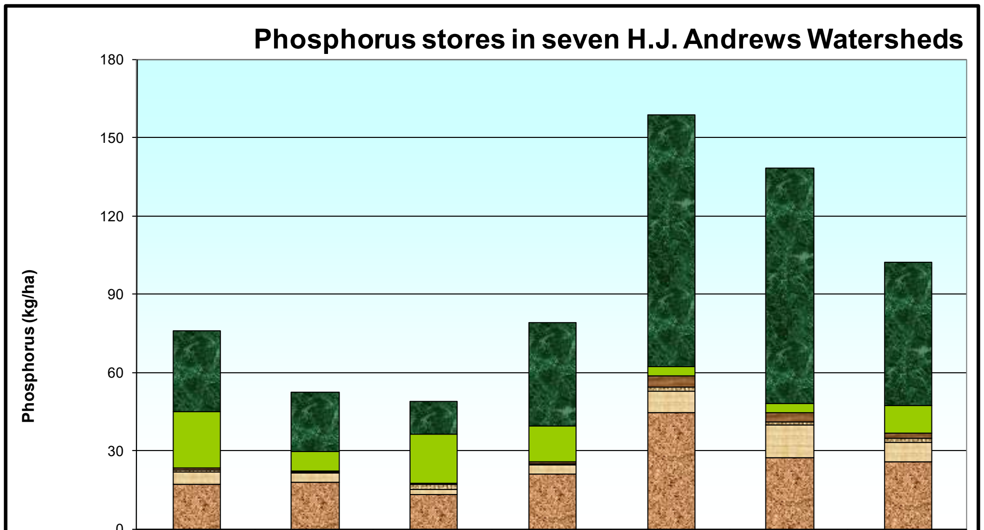
Phosphorus stores in control stands

Total phosphorus stored in the control stands ranged from 102 to 159 Kg/ha. While live trees constitute 73% of the total biomass in control stands, they store on average only 60% of the total phosphorus with values ranging from 55 to 96 Kg/ha. Conversely, the forest floor contains only 6% of the total biomass, yet contains on average 25% of the total phosphorus with values between 26 and 45 Kg/ha. CWD constitutes the next largest pool of phosphorus with values ranging from 9 to 16 Kg/ha, or 9% of the total on average. Understory plants store only 0.34% of the total biomass, yet represent on average 5% of the total phosphorus stored with values ranging from 3 to 10 Kg/ha. Fine woody debris contained 1.1 to 1.7 Kg/ha, or an average of only 1% of the total phosphorus.

Phosphorus stores in cut stands

Total phosphorus stored in cut stands ranged in value from 49 to 79 Kg/ha. Similar to the control stands, live trees dominated at 53% of the total biomass, yet they stored on average only 40% of the total phosphorus with values between 12 to 39 Kg/ha. The forest floor contained the next most significant store of phosphorus with values ranging from 13 to 21 Kg/ha, or an average 28% of the total. Unlike the control stands, however, understory plants store almost as much phosphorus as the forest floor with values ranging from 7 to 21 Kg/ha, which translates to almost 25% of the total. Of the remaining 7%, CWD contained an average 6% of the total phosphorus with values between 2 and 5 Kg/ha. Fine woody debris stored an average 1% of the total with values between 0.6 and 2 Kg/ha.

Figure 4. Phosphorous stores in seven small watersheds by component



	WS01	WS06	WS07	WS10	WS02	WS08	WS09
Total P	76.49	52.80	49.25	79.42	159.19	138.65	102.47
Live Tree	30.98	22.83	12.60	39.32	96.43	90.29	54.76
Understory	21.83	7.40	18.87	13.79	3.74	3.45	10.41
Snag/Stump	0.67	0.16	0.14	0.78	4.36	3.43	2.01
FWD	0.71	0.64	1.95	0.64	1.40	1.10	1.69
Logs	4.82	3.52	2.23	3.23	8.08	12.75	7.57
Forest Floor	17.48	18.25	13.46	21.66	45.18	27.63	26.03

Table 5. Percent Phosphorus stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	40.50	28.54	0.88	0.93	6.30	22.85
WS06	43.24	14.02	0.30	1.21	6.67	34.56
WS07	25.58	38.31	0.28	3.96	4.53	27.33
WS10	49.51	17.36	0.98	0.81	4.07	27.27
WS02	60.58	2.35	2.74	0.88	5.08	28.38
WS08	65.12	2.49	2.47	0.79	9.20	19.93
WS09	53.44	10.16	1.96	1.65	7.39	25.40

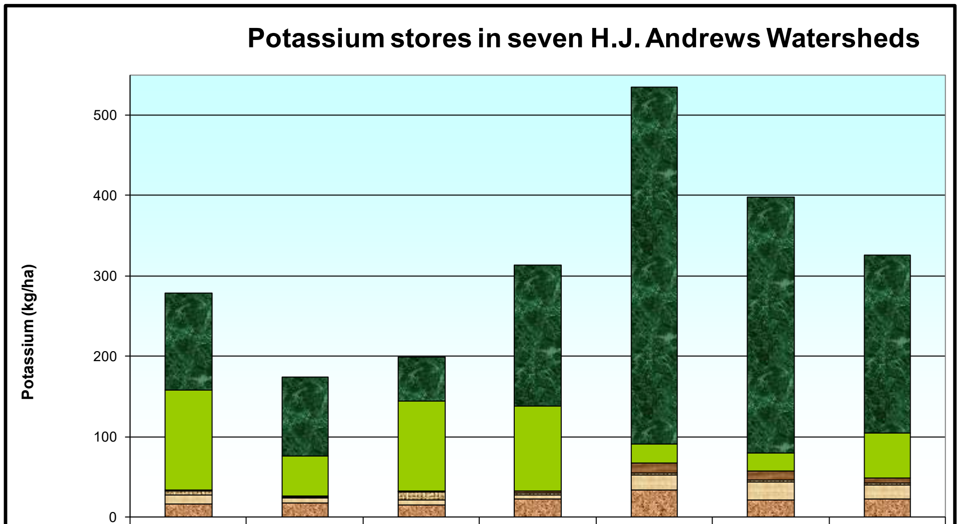
Potassium stores in control stands

Total potassium stored in control stands ranged from 327 to 535 Kg/ha. Following the pattern of biomass, live trees contained the largest portion, with values between 221 and 444 Kg/ha, or an average of 77% of the total potassium. Unlike biomass, however, the next largest store of potassium was contained in the understory plants with values ranging from 22 to 56 Kg/ha, or 9% of the total on average. CWD stored an average 7% of the total potassium with values between 23 and 34 Kg/ha. Forest floor material contained 6% of the total, with values between 21 and 35 Kg/ha. Fine woody debris contained 2 to 3 Kg/ha, or slightly less than 1% of the total potassium.

Potassium stores in cut stands

Total potassium stored in cut stands ranged from 175 to 314 Kg/ha. Similar to the control stands, the vast majority of potassium in cut stands was stored in the live plants. Live trees contained on average 45% of the total with values between 54 and 175 Kg/ha. Understory plants, contained only 4% of the total biomass, yet stored almost as much potassium as the trees with values ranging from 50 to 123 Kg/ha or 41% of the total. Forest floor material was the next largest pool with an average of 8% of the total potassium, and values ranging from 16 to 23 Kg/ha. CWD stored between 5 and 13 Kg/ha or 4% of the total on average. Fine woody debris stored between 2 to 11 Kg/ha, an average 2% of the total.

Figure 5. Potassium stores in seven small watersheds by component



	WS01	WS06	WS07	WS10	WS02	WS08	WS09
Total K	279.10	174.64	199.62	314.18	535.50	399.12	327.02
Live Tree	120.70	98.00	54.00	175.61	444.31	318.31	221.06
Understory	123.47	49.80	111.85	105.45	23.14	22.60	56.54
Snag/Stump	1.87	0.53	0.50	2.51	12.33	10.99	6.29
FWD	4.28	1.93	11.72	1.92	2.37	2.20	2.54
Logs	11.30	6.13	5.10	5.47	18.21	23.53	17.45
Forest Floor	17.48	18.25	16.45	23.22	35.14	21.49	23.14

Table 6. Percent Potassium stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	43.25	44.24	0.67	1.53	4.05	6.26
WS06	56.12	28.52	0.30	1.11	3.51	10.45

WS07	27.05	56.03	0.25	5.87	2.55	8.24
WS10	55.89	33.56	0.80	0.61	1.74	7.39
WS02	82.97	4.32	2.30	0.44	3.40	6.56
WS08	79.75	5.66	2.75	0.55	5.90	5.38
WS09	67.60	17.29	1.92	0.78	5.34	7.08

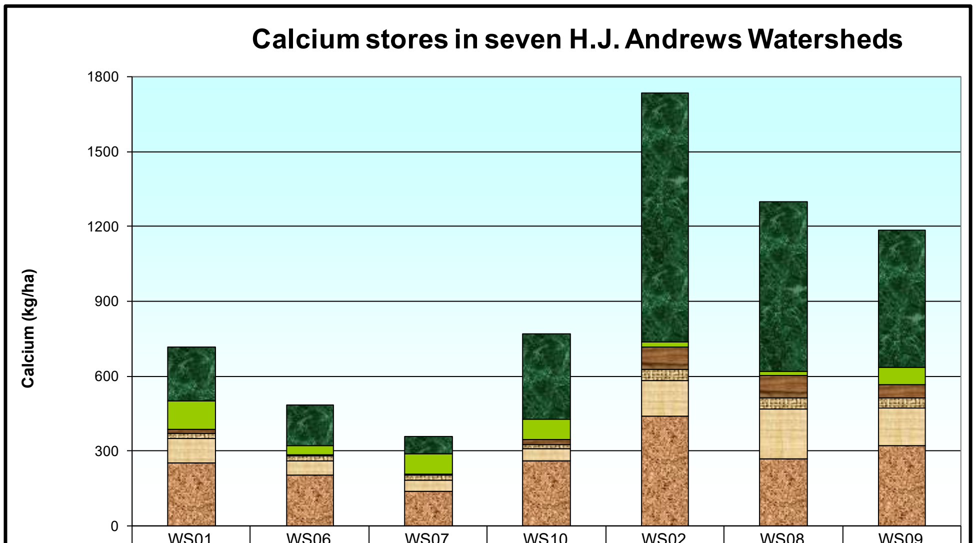
<u>Calcium stores in control stands</u>

Total calcium values in control stands ranged from 1189 to 1739 Kg/ha. Live trees stored the most calcium with an average 52% of the total and values between 550 and 1000 Kg/ha. Unlike the trend in biomass, with forest floor material comprising only 6% of the total, it was found to contain an average 24% of the total calcium with values ranging from 270 to 442 Kg/ha. CWD stored between 201 and 288 Kg/ha or 18% of the total calcium on average. Fine woody debris and understory plants both contained an average 3% of the total calcium with values ranging from 42 to 47 Kg/ha and 16 to 71 Kg/ha respectively.

<u>Calcium stores in cut stands</u>

Total calcium values in cut stands ranged from 360 to 773 Kg/ha. While comprising on average only 15% of the total biomass, the forest floor contained the largest pool with 38% of the total calcium on average and values ranging from 142 to 263 Kg/ha, which is very close to the percent found in live trees with values between 66 and 343 Kg/ha or 32% of the total. Understory plants contained the next largest pool with values ranging from 37 to 114 Kg/ha or an average 14% of the total calcium. CWD stored an average 13% of the total calcium with values between 47 and 112 Kg/ha. Fine woody debris contained between 18 and 22 Kg/ha, or an average 4% of the total calcium.

Figure 6. Calcium stores in seven small watersheds by component



	WS01	WS06	WS07	WS10	WS02	WS08	WS09
Total Ca	718.96	488.53	360.39	773.20	1739.91	1303.72	1189.36
Live Tree	215.66	164.83	66.50	343.08	1000.64	682.23	550.40
Understory	114.38	37.18	82.33	79.79	20.40	15.97	71.37
Snag/Stump	15.28	4.21	3.97	19.78	89.92	87.46	51.13
FWD	19.99	20.54	22.46	17.90	44.81	47.28	42.34
Logs	97.23	55.54	43.04	49.53	142.38	200.64	150.22
Forest Floor	256.42	206.23	142.09	263.12	441.76	270.14	323.90

Table 7. Percent Calcium stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	30.00	15.91	2.13	2.78	13.52	35.67
WS06	33.74	7.61	0.86	4.20	11.37	42.21
WS07	18.45	22.84	1.10	6.23	11.94	39.43
WS10	44.37	10.32	2.56	2.32	6.41	34.03
WS02	57.51	1.17	5.17	2.58	8.18	25.39
WS08	52.33	1.22	6.71	3.63	15.39	20.72
WS09	46.28	6.00	4.30	3.56	12.63	27.23

Magnesium stores in control stands

Total magnesium stored in control stands ranged from 118 to 143 Kg/ha. Live trees dominate this pool, storing an average 46% of the total with values between 49 and 75 Kg/ha. Forest floor material stored a large portion of the magnesium with values ranging from 21 to 38 Kg/ha, or an average of 24% of the total. CWD contained almost as much as the forest floor with an average 23% of the total and values between 23 and 38 Kg/ha. Understory plants stored between 3 to 15 Kg/ha, or an average 6% of the total magnesium. FWD contained only 1% of the total with values between 1 and 2 Kg/ha.

Magnesium stores in cut stands

Total magnesium stored in cut stands ranged from 48 to 87 Kg/ha. Unlike the control stands, forest floor material stored the most magnesium with values ranging from 15 to 25 Kg/ha or 32% of the total on average. Live trees and understory plants each stored 25% of the total magnesium on average with values between 7 to 30 Kg/ha and 8 to 22 Kg/ha respectively. CWD contained an average 14% of the total magnesium with values ranging from 5 to 14 Kg/ha. Similar to the control stands, FWD stored only 4% of the total with values between 2 and 3 Kg/ha.

Figure 7. Magnesium stores in seven small watersheds by component

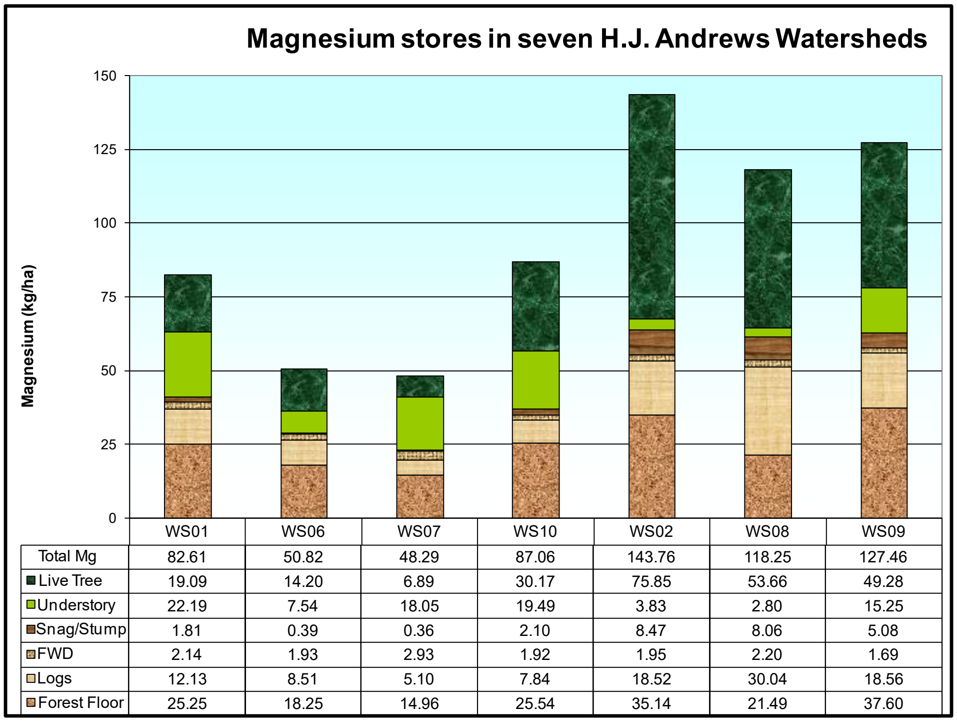


Table 8. Percent Magnesium stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	23.11	26.86	2.19	2.59	14.68	30.57
WS06	27.94	14.84	0.77	3.80	16.75	35.91
WS07	14.27	37.38	0.75	6.07	10.56	30.98
WS10	34.65	22.39	2.41	2.21	9.01	29.34
WS02	52.76	2.66	5.89	1.36	12.88	24.44
WS08	45.38	2.37	6.82	1.86	25.40	18.17
WS09	38.66	11.96	3.99	1.33	14.56	29.50

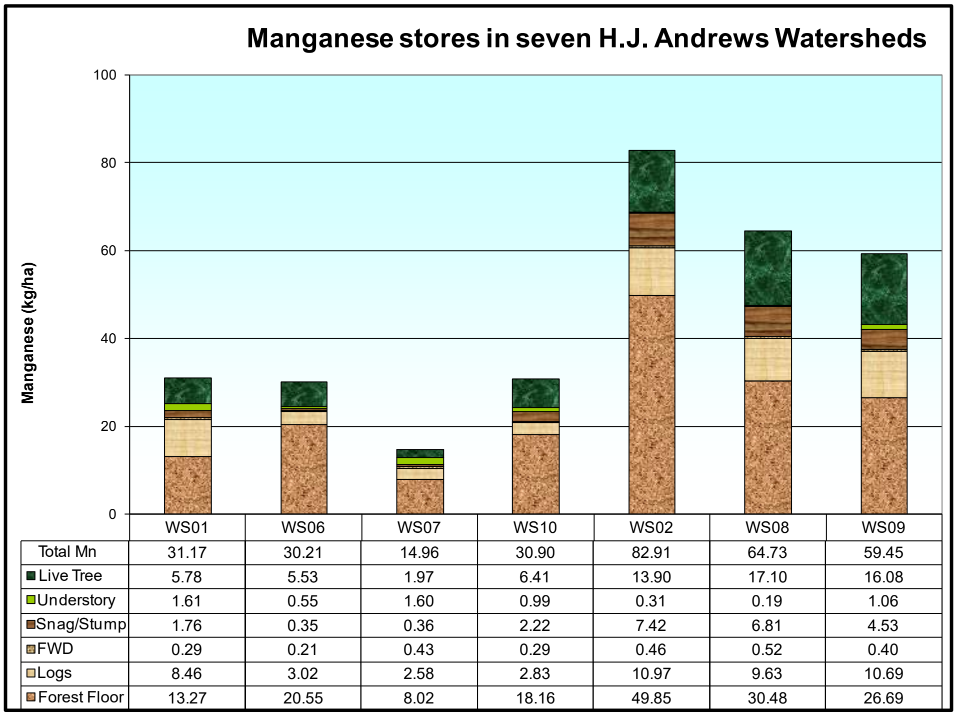
Manganese stores in control stands

Total manganese stored in control stands ranged from 64 to 83 Kg/ha. The vast majority of manganese was contained in the forest floor material with values between 27 to 50 Kg/ha, or an average 51% of the total. CWD stored the next largest amount at 24% of the total with values ranging from 15 to 18 Kg/ha. Live trees stored nearly as much as CWD with values between 13 and 17 Kg/ha, or an average 23% of the total manganese. Understory plants and FWD both stored on average only 1% of the total with values ranging from 0.2 to 1 Kg/ha and 0.4 to 0.5 Kg/ha respectively.

Manganese stores in cut stands

Total manganese stored in cut stands ranged from 15 to 31 Kg/ha. Similar to the control stands, forest floor material contained the majority of manganese at 56% of the total with values between 8 and 20 Kg/ha. CWD values ranged from 3 to 10 Kg/ha, or an average 20% of the total manganese. Live trees comprised 18% of the total on average with values ranging from 2 to 6 Kg/ha. The understory plants contained 5% of the total manganese on average with values between 0.5 and 1.6 Kg/ha. FWD stored 0.2 to 0.4 Kg/ha, and average 1% of the total manganese.

Figure 8. Manganese stores in seven small watersheds by component



	WS01	WS06	WS07	WS10	WS02	WS08	WS09
Total Mn	31.17	30.21	14.96	30.90	82.91	64.73	59.45
Live Tree	5.78	5.53	1.97	6.41	13.90	17.10	16.08
Understory	1.61	0.55	1.60	0.99	0.31	0.19	1.06
Snag/Stump	1.76	0.35	0.36	2.22	7.42	6.81	4.53
FWD	0.29	0.21	0.43	0.29	0.46	0.52	0.40
Logs	8.46	3.02	2.58	2.83	10.97	9.63	10.69
Forest Floor	13.27	20.55	8.02	18.16	49.85	30.48	26.69

Table 9. Percent Manganese stored within each component

STAND	Live Tree	Understory	Snag/Stump	FWD	Logs	Forest Floor
WS01	18.54	5.17	5.65	0.93	27.14	42.57
WS06	18.31	1.82	1.16	0.70	10.00	68.02
WS07	13.17	10.70	2.41	2.87	17.25	53.61
WS10	20.74	3.20	7.18	0.94	9.16	58.77
WS02	16.77	0.37	8.95	0.55	13.23	60.13
WS08	26.42	0.29	10.52	0.80	14.88	47.09
WS09	27.05	1.78	7.62	0.67	17.98	44.89

Discussion

This preliminary report provides bulk biomass and nutrient store data for aboveground live and dead plant material within different watersheds at the HJA. This data is intended as a resource and can be used for analysis in multiple ways. We compared biomass and nutrient stores amongst cut watersheds, amongst uncut watersheds, and between cut and uncut watersheds. Furthermore, we also compared and contrasted biomass and nutrient pools amongst components within one watershed.

Different components store different fractions of biomass and nutrients depending on the element being considered. While biomass and carbon content are proportional to each other (e.g. biomass is composed of approximately 50% carbon), this is not the case for the other elements examined. Foliage and leaf litter store a large portion of the nitrogen pool within watersheds, so while live trees comprise 53 to 73% of the total biomass, they store only 21 to 37% of the total nitrogen because foliage comprises only 4 to 9% of the biomass of an individual tree on average. Within the cut watersheds, where the live trees are smaller than in the uncut watersheds, the forest floor material contained the largest pool of nitrogen, due to the fact that it is composed mostly of fallen foliage. Another example of components storing differing nutrient fractions is potassium. It is interesting to note that in both the cut and uncut watersheds, live plants (trees and understory) stored 86% of the total potassium even though combined they comprise 57 to 73% of the total biomass in the watersheds.

The proportions of nutrients differed within components based on stand age. The understory plants within the younger cut watersheds stored between 25 to 41% of the total phosphorus, total potassium, and total magnesium in those stands. In the older uncut watersheds, where less light reaches the understory layer, this component only stores 5 to 9% of the total pools for phosphorus, potassium, and magnesium within these stands. The proportion of nutrients stored within the CWD component also varied with stand age, for example in the younger cut stands this component stored an average 14% of the total magnesium whereas in the older uncut stands the amount of total magnesium stored in CWD was 23% of the total, almost a two-fold increase from the younger watersheds.

While WS09 is in the category of uncut watersheds, it tended to be lower than WS08 and WS02 for total biomass and many nutrient stores. It may be that WS09 had a higher percentage of plots that contained mature forest as opposed to old-growth, and therefore it is more representative of a mature forested watershed, which would be intermediate between young growth and old-growth. This supposition is supported by some of the biomass measurements, for example the percent of total biomass in understory plants for WS02 and WS08 was 0.22, but WS09 contained 0.58%.

WS10 had significantly higher biomass and nutrient store values than WS06 and WS07, even though WS10 was clearcut a year later the other two watersheds. WS10 also had biomass and nutrient stores very similar to or even higher than WS01, despite being a decade younger. Perhaps the lack of fire after clearcutting in WS10 facilitated faster tree growth due to more nutrient availability from the intact forest floor and other fine woody material. The total biomass and nutrient stores for WS07 are lower than the other cut stands, but shelterwood harvest may have slowed down growth of trees and trees were also cut during a thinning operation in 2001, however, most of that biomass remained at the time of the inventory of that watershed.

Future efforts to complete the inventory of biomass and nutrient stores in these watersheds should include soil and belowground biomass components. Adding these would help to more accurately model the nutrient cycling within watersheds at the HJA. Furthermore, future analysis should separate mature forest plots from old-growth forest plots within the uncut watersheds to shed light on the differences between mature and old-growth forests in terms of total biomass and nutrient stores. This data set can also be used to compare and contrast with the biomass data collected from the Early Succession Synthesis Area stands as well as the reference stands to create a more complete picture of biomass and nutrient stores within watersheds at the HJA.

Acknowledgements

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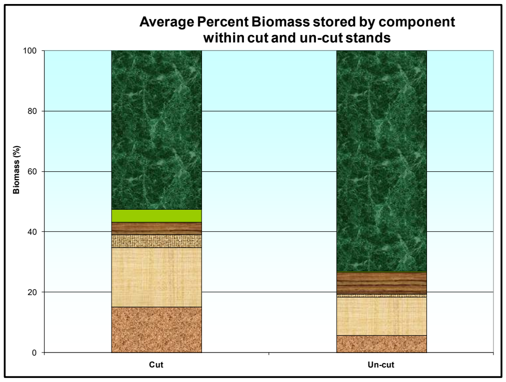
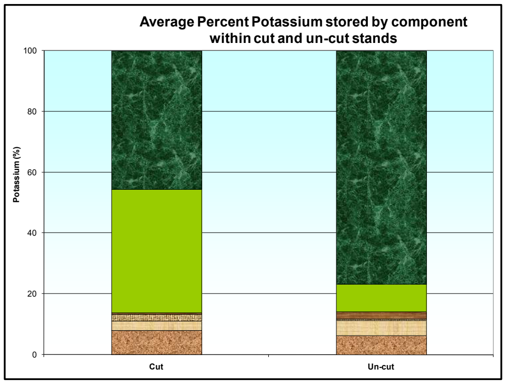
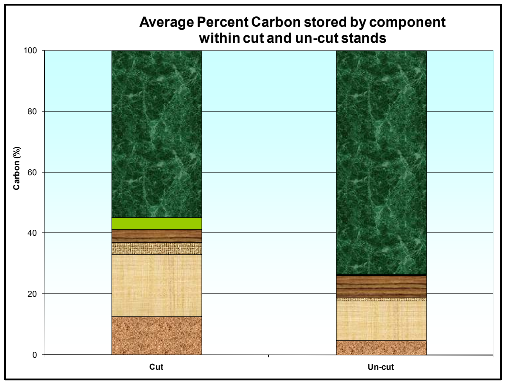
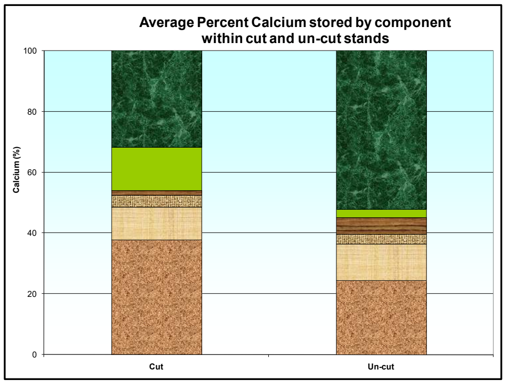
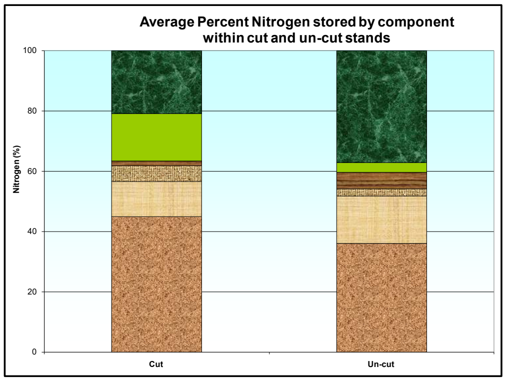
Appendix 1. Percentage of total nutrients within each plant component by cut type

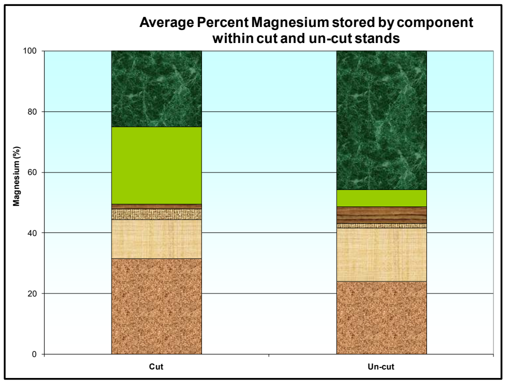


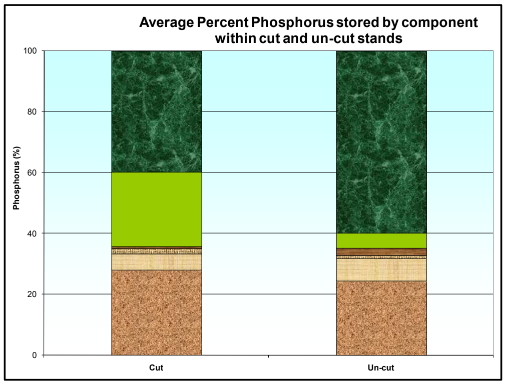


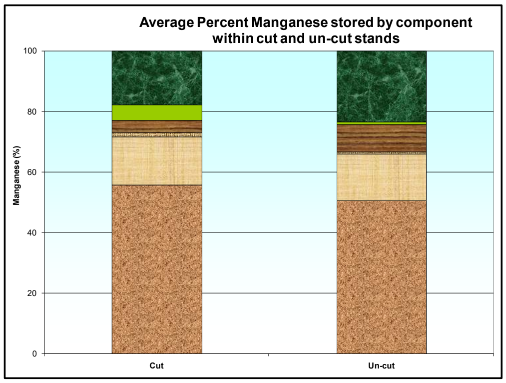




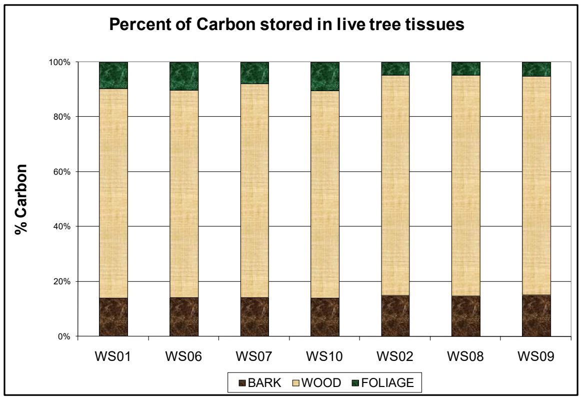


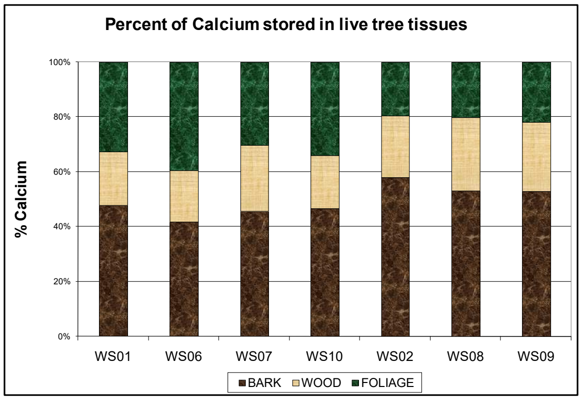


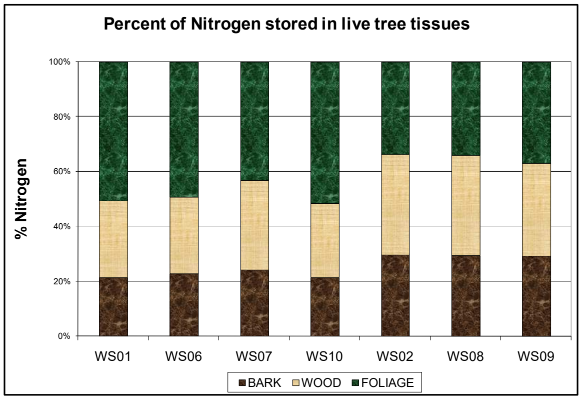


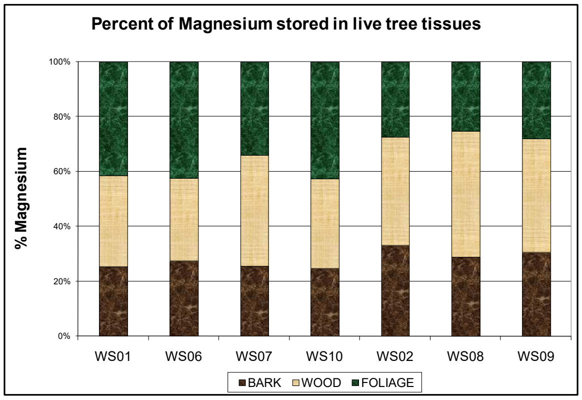


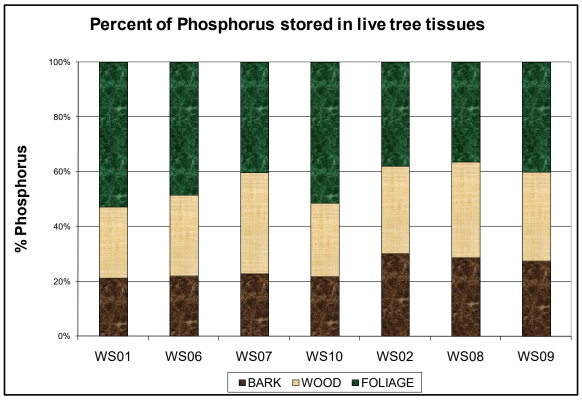
Appendix 2. Percent nutrients stored by tissue in live trees by watershed

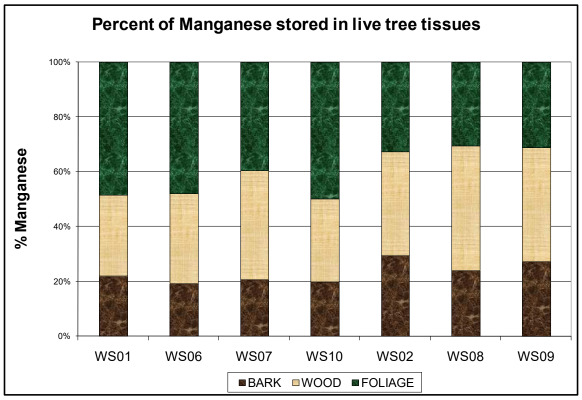


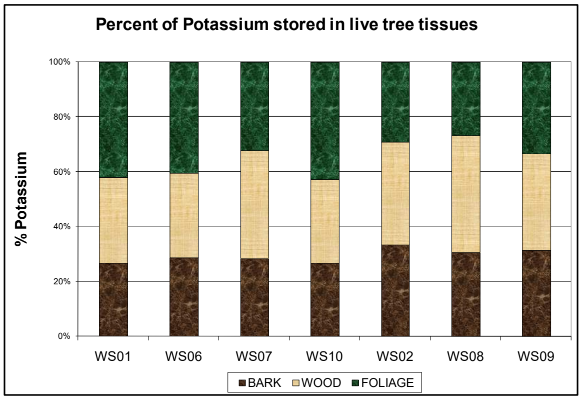












Appendix 3. Nutrient stores by watershed and plant component

Table 10. Total nutrients stored by watershed (Kg/ha, except Carbon)

STAND	Total N	Total P	Total K	Total CA	Total Mg	Total Mn	Total C MgHa
WS01	658.43	76.49	279.1	718.96	82.61	31.17	128.09
WS06	588.59	52.8	174.64	488.53	50.82	30.21	90.98
WS07	498.67	49.25	199.62	360.39	48.29	14.96	60.9
WS10	658.18	79.42	314.18	773.2	87.06	30.9	120.97
WS02	1336.83	159.19	535.5	1739.91	143.76	82.91	431.19
WS08	1313.68	138.65	399.12	1303.72	118.25	64.73	439.44
WS09	981.55	102.47	327.02	1189.36	127.46	59.45	385.27

Table 11. Nutrient stores in live trees within seven small watersheds at the HJA

STAND	N	err_n	P	err_p	K	err_k	CA	err_ca	MG	err_mg	MN	err_mn
WS01	145.69		30.98		120.70		215.66		19.09		5.78	
WS06	128.28		22.83		98.00		164.83		14.20		5.53	
WS07	60.33		12.60		54.00		66.50		6.89		1.97	
WS10	181.58		39.32		175.61		343.08		30.17		6.41	
WS02	561.22		96.43		444.31		1000.64		75.85		13.90	
WS08	432.35		90.29		318.31		682.23		53.66		17.10	
WS09	356.48		54.76		221.06		550.40		49.28		16.08	

Table 12. Nutrient stores in understory plants within seven small watersheds at the HJA

STAND	N	err_n	P	err_p	K	err_k	CA	err_ca	MG	err_mg	MN	err_mn
WS01	118.17		21.83		123.47		114.38		22.19		1.61	
WS06	49.14		7.40		49.80		37.18		7.54		0.55	
WS07	115.90		18.87		111.85		82.33		18.05		1.60	
WS10	85.78		13.79		105.45		79.79		19.49		0.99	
WS02	19.46		3.74		23.14		20.40		3.83		0.31	
WS08	21.81		3.45		22.60		15.97		2.80		0.19	
WS09	63.85		10.41		56.54		71.37		15.25		1.06	

Table 13. Nutrient stores in snags and stumps within seven small watersheds at the HJA

STAND	N	err_n	P	err_p	K	err_k	CA	err_ca	MG	err_mg	MN	err_mn
WS01	15.48	1.26	0.67	0.05	1.87	0.17	15.28	1.35	1.81	0.15	1.76	0.19

WS06	3.84	0.43	0.16	0.02	0.53	0.05	4.21	0.42	0.39	0.05	0.35	0.04
WS07	3.47	0.38	0.14	0.02	0.50	0.05	3.97	0.42	0.36	0.04	0.36	0.04
WS10	18.49	2.18	0.78	0.09	2.51	0.30	19.78	2.37	2.10	0.26	2.22	0.34
WS02	79.71	12.80	4.36	1.12	12.33	2.22	89.92	15.28	8.47	1.39	7.42	1.40
WS08	77.84	14.96	3.43	0.63	10.99	2.23	87.46	19.60	8.06	1.43	6.81	1.40
WS09	47.26	11.19	2.01	0.46	6.29	1.58	51.13	12.64	5.08	1.21	4.53	1.41

Table 14. Nutrient stores in fine woody debris within seven small watersheds at the HJA

STAND	N	err_n	P	err_p	K	err_k	CA	err_ca	MG	err_mg	MN	err_mn
WS01	28.55	2.10	0.71	0.05	4.28	0.32	19.99	1.47	2.14	0.16	0.29	0.02
WS06	31.45	4.36	0.64	0.09	1.93	0.27	20.54	2.85	1.93	0.27	0.21	0.03
WS07	42.00	3.01	1.95	0.14	11.72	0.84	22.46	1.61	2.93	0.21	0.43	0.03
WS10	16.94	1.62	0.64	0.06	1.92	0.18	17.90	1.71	1.92	0.18	0.29	0.03
WS02	29.17		1.40		2.37		44.81		1.95		0.46	
WS08	40.13	2.60	1.10	0.07	2.20	0.14	47.28	3.06	2.20	0.14	0.52	0.03
WS09	18.21	2.34	1.69	0.22	2.54	0.33	42.34	5.43	1.69	0.22	0.40	0.05

Table 15. Nutrient stores in logs within seven small watersheds at the HJA

STAND	N	err_n	P	err_p	K	err_k	CA	err_ca	MG	err_mg	MN	err_mn
WS01	106.15	12.78	4.82	0.58	11.30	1.48	97.23	12.44	12.13	1.47	8.46	1.32
WS06	69.43	11.09	3.52	0.58	6.13	0.97	55.54	8.77	8.51	1.40	3.02	0.55
WS07	47.13	7.88	2.23	0.40	5.10	0.87	43.04	6.98	5.10	0.91	2.58	0.46
WS10	63.58	13.71	3.23	0.70	5.47	1.24	49.53	10.99	7.84	1.75	2.83	0.95
WS02	156.56	19.22	8.08	1.10	18.21	2.53	142.38	18.58	18.52	2.31	10.97	1.86
WS08	246.48	26.18	12.75	1.49	23.53	2.09	200.64	19.20	30.04	3.62	9.63	1.05
WS09	163.26	29.89	7.57	1.36	17.45	3.65	150.22	30.44	18.56	3.37	10.69	2.58

Table 16. Nutrient stores in the forest floor within seven small watersheds at the HJA

STAND	N	err_n	P	err_p	K	err_k	CA	err_ca	MG	err_mg	MN	err_mn
WS01	244.39	24.98	17.48	0.95	17.48	20.80	256.42	2.05	25.25	1.42	13.27	0.00
WS06	306.45	39.64	18.25	1.22	18.25	22.97	206.23	2.03	18.25	2.03	20.55	0.02
WS07	229.84	19.26	13.46	0.72	16.45	13.59	142.09	1.43	14.96	1.29	8.02	0.02
WS10	291.81	57.04	21.66	2.23	23.22	44.63	263.12	4.33	25.54	3.67	18.16	0.04
WS02	490.71		45.18		35.14		441.76		35.14		49.85	
WS08	495.07	99.51	27.63	3.33	21.49	48.84	270.14	3.89	21.49	5.00	30.48	0.04
WS09	332.49	52.84	26.03	2.62	23.14	48.97	323.90	5.68	37.60	3.93	26.69	0.10

Appendix 4. Wet chemistry data

STAND	TYPE	SPECIES	REPL	%C	%N	P ppm	K ppm	CA ppm	MG ppm	MN ppm
ALL	RW	MIX	1	48.6	0.51					
ALL	RW	MIX	2	48.9	0.68					
WS01	FWD	MIX	1	46.3	0.40	100	600	2800	300	41
WS01	H	MIX	1	45.9	1.37	2447	20670	5576	2548	106
WS01	OM	MIX	1	35.7	1.11	900	900	13200	1300	683
WS01	OM	MIX	2	35.0	1.11					
WS01	SH	MIX	1	44.3	1.72	3382	12000	22820	3484	315
WS01	SL	MIX	1	46.9	0.92	1532	12710	6211	1484	80
WS01	TB	ACMA	1	45.2	0.26	749	4897	27400	1111	113
WS01	TB	PSME	1	52.7	0.14	337	1768	2400	179	37
WS01	TF	ACMA	1	45.5	2.31	6214	16480	19960	3565	209
WS01	TF	PSME	1	49.7	0.85	2638	7649	11240	1217	558
WS01	TW	ACMA	1	47.1	0.06	147	1408	1440	319	8
WS01	TW	PSME	1	47.9	0.04	24	109	253	19	10
WS02	FWD	MIX	1	48.3	0.29	200	300	4700	200	47
WS02	H	MIX	1	46.0	1.20	2529	19120	5397	2543	80
WS02	OM	MIX	1	37.5	0.98	900	700	8800	700	993
WS02	SH	MIX	1	46.2	1.13	2246	8600	16460	2247	248
WS02	SL	MIX	1	46.7	0.75	1289	12100	5702	1395	84
WS02	TB	ACMA	1	45.1	0.37	788	4572	24910	1029	119
WS02	TB	PSME	1	55.9	0.12	158	719	2831	120	24
WS02	TB	TABR	1	43.1	0.44	770	4841	33280	1321	89
WS02	TB	THPL	1	48.6	0.19	269	1980	8810	272	13
WS02	TB	TSHE	1	51.6	0.14	301	1590	8234	256	48
WS02	TF	ACMA	1	45.6	1.92	3872	13310	14890	2854	172
WS02	TF	ACMA	2	44.7	1.91	3734	12350	14520	2729	167
WS02	TF	ACMA	3	45.5	1.92	3683	12340	14270	2632	152
WS02	TF	PSME	1	50.1	0.85	2227	6790	9038	946	383
WS02	TF	TABR	1	50.6	0.93	1311	8374	10240	1306	119
WS02	TF	TABR	2	50.4	0.92	1255	7630	9582	1182	76
WS02	TF	THPL	1	50.2	0.77	1243	6208	15920	1089	77
WS02	TF	TSHE	1	49.8	0.87	1964	5415	6565	1280	167
WS02	TW	ACMA	1	46.7	0.06	160	1224	1060	199	8
WS02	TW	PSME	1	48.2	0.04	26	158	190	22	10
WS02	TW	TABR	1	49.3	0.06	25	297	874	98	16
WS02	TW	THPL	1	49.0	0.06	33	262	1144	83	3
WS02	TW	TSHE	1	47.8	0.04	191	882	600	115	18
WS06	FWD	MIX	1	46.1	0.49	100	300	3200	300	33
WS06	H	MIX	1	44.0	1.70	2777	27850	6723	2582	264
WS06	OM	MIX	1	37.9	1.10	1000	1000	11300	1000	1126
WS06	OM	MIX	2	38.3	1.20					
WS06	SH	MIX	1	46.8	1.31	2013	10490	13350	2327	201
WS06	SL	MIX	1	46.8	1.01	1469	12500	4500	1234	57
WS06	TB	CACH	1	46.6	0.24	243	2616	6132	644	46
WS06	TB	PSME	1	51.8	0.18	414	2086	2391	194	49
WS06	TB	PSME	2	52.0	0.18	401	1997	2250	176	34
WS06	TB	THPL	1	48.5	0.24	427	2947	10490	615	22
WS06	TF	CACH	1	48.9	0.71	678	3815	11670	1462	94

WS06	TF	PSME	1	49.9	0.90	2096	6424	10330	1059	770
WS06	TF	THPL	1	50.6	0.89	1209	6795	17370	752	68
WS06	TW	CACH	1	49.3	0.06	191	870	639	96	17
WS06	TW	PSME	1	47.7	0.04	32	166	215	25	13
WS06	TW	THPL	1	48.3	0.06	68	519	1152	105	11
WS07	FWD	MIX	1	46.2	0.43	200	1200	2300	300	44
WS07	H	MIX	1	44.1	1.64	2789	26270	6649	2225	211
WS07	OM	MIX	1	36.4	1.24	900	1100	9500	1000	536
WS07	OM	MIX	2	35.9	1.19					
WS07	SH	MIX	1	46.4	1.50	2314	10390	12540	2601	270
WS07	SL	MIX	1	46.4	0.94	1657	13090	4823	1202	66
WS07	TB	CACH	1	46.4	0.18	169	1441	5926	235	37
WS07	TB	PSME	1	51.8	0.18	436	2671	1938	201	38
WS07	TB	TSHE	1	51.6	0.22	527	2455	3814	217	75
WS07	TF	CACH	1	47.2	0.82	793	4123	10820	830	146
WS07	TF	PSME	1	49.4	0.86	2078	6433	9334	956	365
WS07	TF	TSHE	1	49.9	0.85	1971	4972	6937	856	213
WS07	TF	TSHE	2	50.0	0.85	1858	4824	6654	859	235
WS07	TW	CACH	1	46.8	0.06	203	822	821	170	28
WS07	TW	PSME	1	47.5	0.04	31	193	199	26	12
WS07	TW	TSHE	1	48.1	0.05	326	1171	790	122	30
WS08	FWD	MIX	1	47.1	0.37	100	200	4300	200	47
WS08	H	MIX	1	44.1	1.61	3124	24590	7719	2047	126
WS08	OM	MIX	1	39.6	1.16	900	700	8800	700	993
WS08	OM	MIX	2	40.5	1.03					
WS08	SH	MIX	1	46.3	1.09	1650	7825	9963	1496	120
WS08	SL	MIX	1	46.2	0.86	1325	10910	5072	1008	48
WS08	TB	ABMA	1	47.0	0.15	332	1914	12060	139	63
WS08	TB	ABPR	1	50.2	0.16	276	1984	4136	178	46
WS08	TB	PSME	1	53.3	0.14	174	674	3648	147	27
WS08	TB	THPL	1	47.0	0.17	337	2326	10430	335	26
WS08	TB	TSHE	1	50.4	0.14	239	1071	6304	175	43
WS08	TB	TSHE	2	50.2	0.13	225	987	5720	166	46
WS08	TF	ABMA	1	48.4	0.75	1245	6146	7872	715	193
WS08	TF	ABPR	1	49.5	0.64	1041	5103	10510	522	213
WS08	TF	PSME	1	48.2	0.77	2110	4629	7858	874	472
WS08	TF	THPL	1	47.8	0.62	947	4588	14720	738	67
WS08	TF	THPL	2	47.9	0.62	915	4333	14270	698	49
WS08	TF	TSHE	1	49.0	0.70	1714	3825	4700	717	242
WS08	TW	ABMA	1	47.5	0.03	34	398	918	87	21
WS08	TW	ABPR	1	47.2	0.03	26	847	922	137	19
WS08	TW	PSME	1	47.8	0.03	19	81	170	19	13
WS08	TW	THPL	1	48.8	0.05	40	205	847	62	10
WS08	TW	TSHE	1	48.0	0.03	238	1011	698	121	21
WS08	TW	TSHE	2	47.9	0.03	243	990	708	120	21
WS09	FWD	MIX	1	49.6	0.21	200	300	5000	200	47
WS09	H	MIX	1	45.7	1.22	2244	20660	6450	2592	88
WS09	OM	MIX	1	35.7	0.87	900	800	11200	1300	923
WS09	OM	MIX	2	34.0	0.85					
WS09	SH	MIX	1	44.5	1.89	3158	11090	24650	4669	389
WS09	SL	MIX	1	47.2	0.84	1246	11260	7196	1910	86
WS09	TB	ACMA	1	44.2	0.30	663	4174	20050	1140	74

WS09	TB	CACH	1	54.8	0.20	137	673	4183	217	36
WS09	TB	PSME	1	55.2	0.12	173	691	2787	131	32
WS09	TB	TABR	1	43.7	0.41	667	3508	39600	1061	89
WS09	TB	THPL	1	49.2	0.20	303	1836	8303	246	18
WS09	TB	TSHE	1	51.8	0.18	387	2343	5400	256	60
WS09	TF	ACMA	1	45.7	2.00	4689	14450	20350	3087	132
WS09	TF	CACH	1	48.9	0.87	943	4816	8421	959	150
WS09	TF	PSME	1	49.8	0.86	2377	8350	9384	1311	507
WS09	TF	TABR	1	50.7	1.01	1675	8273	12200	1558	96
WS09	TF	THPL	1	51.4	0.74	999	4989	22630	622	63
WS09	TF	TSHE	1	50.3	0.92	1736	5339	6383	1169	178
WS09	TW	ACMA	1	46.8	0.05	89	673	1814	187	10
WS09	TW	CACH	1	47.4	0.05	208	417	891	138	22
WS09	TW	PSME	1	48.2	0.03	19	94	341	39	15
WS09	TW	TABR	1	48.7	0.06	25	230	856	94	18
WS09	TW	THPL	1	49.0	0.06	37	265	1170	111	4
WS09	TW	TSHE	1	48.1	0.04	122	672	627	90	22
WS10	FWD	MIX	1	46.5	0.26	100	300	2800	300	46
WS10	H	MIX	1	46.3	1.21	2142	20100	4634	2347	89
WS10	OM	MIX	1	35.1	0.90	933	1000	11333	1100	782
WS10	OM	MIX	2	33.2	0.92					
WS10	SH	MIX	1	47.0	1.16	1743	8451	16560	2440	206
WS10	SL	MIX	1	46.8	0.76	1149	10020	7798	2316	64
WS10	TB	ACMA	1	45.0	0.28	827	4375	26020	1089	89
WS10	TB	PSME	1	52.3	0.16	353	2239	2790	227	33
WS10	TB	TSHE	1	50.9	0.18	612	2756	5438	240	44
WS10	TF	ACMA	1	46.6	1.68	2480	14880	14040	1988	245
WS10	TF	PSME	1	50.2	0.77	2309	7261	10620	1142	630
WS10	TF	PSME	2	50.0	0.79	2187	6796	10360	1071	485
WS10	TF	PSME	3	50.1	0.80	2159	6543	9812	1014	436
WS10	TF	TSHE	1	50.7	0.76	1987	6006	7166	1418	203
WS10	TW	ACMA	1	46.6	0.06	182	895	977	263	13
WS10	TW	PSME	1	47.6	0.04	38	194	260	29	12
WS10	TW	PSME	2	47.7	0.04	39	197	255	28	13
WS10	TW	TSHE	1	47.9	0.04	142	657	650	114	19

Metadata for wet chemistry

Field	Code	Definition
TYPE	FS	Fine Woody Debris - Small size class - .6 cm to 2.5 cm diameter
TYPE	FL	Fine Woody Debris - Large size class - > 2.5 cm. to <10.0 cm. diameter
TYPE	H	Herb - non-woody mixed species including ferns and grasses - foliage and stems bulk sample, many individuals
TYPE	SL	Shrub Low - woody mixed species - below 1 meter in height - foliage and stems bulk sample, at least 3 individuals
TYPE	SH	Shrub High - woody mixed species - above 1 meter in height - foliage and stems bulk sample, at least 3 individuals
TYPE	TF	Tree Foliage - major tree species present at a plot - foliage and smallest twigs bulk sample, at least 3 individuals
TYPE	TB	Tree Bark - major tree species present at a plot - inner and outer bark, at least 3 individuals
TYPE	TW	Tree Wood - major tree species present at a plot - increment core of at least 10 cm., at least 3 individuals

TYPE	OM	Organic material associated with forest floor cores
TYPE	RW	Rotten wood material associated with forest floor cores
SPECIES	MIX	Mixed species - sample was collected from Type without regard to species - representative of occurrence %
SPECIES	PSME	Pseudotsuga menziesii
SPECIES	TSHE	Tsuga heterophylla
SPECIES	THPL	Thuja plicata
SPECIES	ACMA	Acer macrophyllum
SPECIES	TABR	Taxus brevifolia
SPECIES	ABPR	Abies procera
SPECIES	ABAM	Abies amabilis
SPECIES	CASH	Castanopsis chrysophylla
SPECIES	PITA	Pinus taeda
		WS10 OM average of WS01,06,07
		WS02 OM average of WS08 and WS09
		WS01 FWD average of WS06, WS07, and WS10
		WS02 FWD average of WS08 and WS09

Appendix 5. Proportion of biomass in bark and wood for CWD by decay class

Decay Class	Tissue	Proportion of total biomass
1	bark	0.16
	wood	0.84
2	bark	0.14
	wood	0.86
3	bark	0.09
	wood	0.91
4	bark	0.04
	wood	0.97
5	bark	0.01
	wood	0.99

Appendix 6. Tree tissue as a proportion of tree biomass by watershed and species

STAND	SPECIES	prop bark	prop wood	prop foliage
WS01	ABAM	0.141	0.789	0.069
WS02	ABAM	0.187	0.768	0.045
WS06	ABAM	0.141	0.789	0.069
WS07	ABAM	0.141	0.789	0.069
WS08	ABAM	0.187	0.768	0.045
WS09	ABAM	0.187	0.768	0.045
WS10	ABAM	0.141	0.789	0.069
WS01	ABGR	0.122	0.843	0.035
WS02	ABGR	0.141	0.84	0.019
WS06	ABGR	0.122	0.843	0.035

WS07	ABGR	0.122	0.843	0.035
WS08	ABGR	0.141	0.84	0.019
WS09	ABGR	0.141	0.84	0.019
WS10	ABGR	0.122	0.843	0.035
WS01	ABMA	0.132	0.791	0.077
WS02	ABMA	0.166	0.799	0.035
WS06	ABMA	0.132	0.791	0.077
WS07	ABMA	0.132	0.791	0.077
WS08	ABMA	0.166	0.799	0.035
WS09	ABMA	0.166	0.799	0.035
WS10	ABMA	0.132	0.791	0.077
WS01	ABPR	0.122	0.843	0.035
WS02	ABPR	0.141	0.84	0.019
WS06	ABPR	0.122	0.843	0.035
WS07	ABPR	0.122	0.843	0.035
WS08	ABPR	0.141	0.84	0.019
WS09	ABPR	0.141	0.84	0.019
WS10	ABPR	0.122	0.843	0.035
WS01	ACMA	0.19	0.777	0.032
WS02	ACMA	0.169	0.82	0.011
WS06	ACMA	0.19	0.777	0.032
WS07	ACMA	0.19	0.777	0.032
WS08	ACMA	0.169	0.82	0.011
WS09	ACMA	0.169	0.82	0.011
WS10	ACMA	0.19	0.777	0.032
WS01	ALRU	0.122	0.867	0.01
WS02	ALRU	0.124	0.856	0.02
WS06	ALRU	0.122	0.867	0.01
WS07	ALRU	0.122	0.867	0.01
WS08	ALRU	0.124	0.856	0.02
WS09	ALRU	0.124	0.856	0.02
WS10	ALRU	0.122	0.867	0.01
WS01	ARME	0.161	0.788	0.051
WS02	ARME	0.183	0.793	0.024
WS06	ARME	0.161	0.788	0.051
WS07	ARME	0.161	0.788	0.051
WS08	ARME	0.183	0.793	0.024
WS09	ARME	0.183	0.793	0.024
WS10	ARME	0.161	0.788	0.051
WS01	CACH	0.177	0.713	0.11
WS02	CACH	0.252	0.706	0.042
WS06	CACH	0.177	0.713	0.11
WS07	CACH	0.177	0.713	0.11
WS08	CACH	0.252	0.706	0.042
WS09	CACH	0.252	0.706	0.042
WS10	CACH	0.177	0.713	0.11
WS01	CADE3	0.079	0.633	0.288
WS02	CADE3	0.099	0.854	0.048
WS06	CADE3	0.079	0.633	0.288
WS07	CADE3	0.079	0.633	0.288

WS08	CADE3	0.099	0.854	0.048
WS09	CADE3	0.099	0.854	0.048
WS10	CADE3	0.079	0.633	0.288
WS01	CONU	0.161	0.788	0.051
WS02	CONU	0.183	0.793	0.024
WS06	CONU	0.161	0.788	0.051
WS07	CONU	0.161	0.788	0.051
WS08	CONU	0.183	0.793	0.024
WS09	CONU	0.183	0.793	0.024
WS10	CONU	0.161	0.788	0.051
WS01	LIDE2	0.079	0.633	0.288
WS02	LIDE2	0.058	0.784	0.158
WS06	LIDE2	0.079	0.633	0.288
WS07	LIDE2	0.079	0.633	0.288
WS08	LIDE2	0.058	0.784	0.158
WS09	LIDE2	0.058	0.784	0.158
WS10	LIDE2	0.079	0.633	0.288
WS01	PILA	0.178	0.731	0.091
WS02	PILA	0.183	0.765	0.052
WS06	PILA	0.178	0.731	0.091
WS07	PILA	0.178	0.731	0.091
WS08	PILA	0.183	0.765	0.052
WS09	PILA	0.183	0.765	0.052
WS10	PILA	0.178	0.731	0.091
WS02	PIMO	0.183	0.765	0.052
WS01	PREM	0.161	0.788	0.051
WS02	PREM	0.183	0.793	0.024
WS06	PREM	0.161	0.788	0.051
WS07	PREM	0.161	0.788	0.051
WS08	PREM	0.183	0.793	0.024
WS09	PREM	0.183	0.793	0.024
WS10	PREM	0.161	0.788	0.051
WS01	PSME	0.137	0.813	0.05
WS02	PSME	0.119	0.86	0.021
WS06	PSME	0.137	0.813	0.05
WS07	PSME	0.137	0.813	0.05
WS08	PSME	0.119	0.86	0.021
WS09	PSME	0.119	0.86	0.021
WS10	PSME	0.137	0.813	0.05
WS01	RHPU	0.161	0.788	0.051
WS02	RHPU	0.183	0.793	0.024
WS06	RHPU	0.161	0.788	0.051
WS07	RHPU	0.161	0.788	0.051
WS08	RHPU	0.183	0.793	0.024
WS09	RHPU	0.183	0.793	0.024
WS10	RHPU	0.161	0.788	0.051
WS01	TABR	0.126	0.786	0.089
WS02	TABR	0.135	0.815	0.049
WS06	TABR	0.126	0.786	0.089
WS07	TABR	0.126	0.786	0.089

WS08	TABR	0.135	0.815	0.049
WS09	TABR	0.135	0.815	0.049
WS10	TABR	0.126	0.786	0.089
WS01	THPL	0.079	0.633	0.288
WS02	THPL	0.058	0.784	0.158
WS06	THPL	0.079	0.633	0.288
WS07	THPL	0.079	0.633	0.288
WS08	THPL	0.058	0.784	0.158
WS09	THPL	0.058	0.784	0.158
WS10	THPL	0.079	0.633	0.288
WS01	TSHE	0.095	0.839	0.066
WS02	TSHE	0.099	0.854	0.048
WS06	TSHE	0.095	0.839	0.066
WS07	TSHE	0.095	0.839	0.066
WS08	TSHE	0.099	0.854	0.048
WS09	TSHE	0.099	0.854	0.048
WS10	TSHE	0.095	0.839	0.066