✦ RESULTS TO DATE

Weather station development

Weather stations were developed using the Arduino open-source prototyping platform and designed to measure the most relevant meteorological factors affecting forest fuel drying (Figure 1). An Arduino pro microcontroller was paired with an Adafruit Datalogger shield and powered using an AA battery pack. Data was logged to an SD card. Sensors were soldered directly to the Adafruit Datalogger shield and included temperature/humidity (SHT-15/75 sensor), soil water potential (Watermark 200ss), and soil and litter temperature (Vishay NTC Thermistor--NTCLE100E3). Measurements were logged during the fire season at 15 minute intervals.

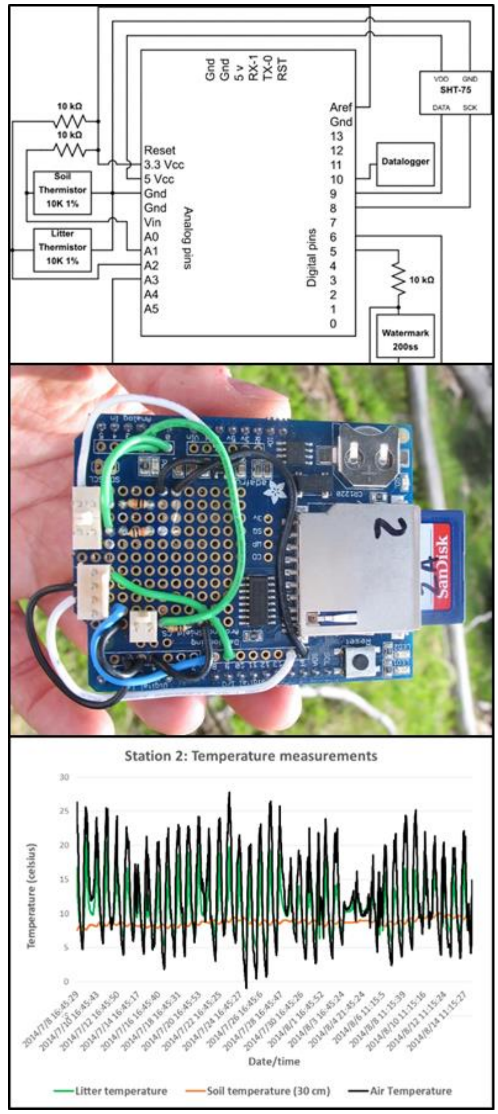

Figure 1. Weather station circuit diagram (top), completed prototype board (middle), and soil, litter, and air temperature for July and August 2014 (bottom).

Fuel moisture across three stages of forest development

Dead FMC varied through the season depending on the fuel particle and the stand development stage (Figure 2). Understory vegetation increased in FMC in the young stand but did not change in the mature stands. Duff FMC trended upward through the season in the mature stands but did not change appreciably in the young stands—perhaps because very little duff was observed at this site. Litter FMC was higher in the mature stands early in the season but all stands had similar FMC at the end of the season. One-hour fuel particle (woody material <0.25” diameter) FMC increased in the young forest site but did not in the mature sites. Ten-hour fuel particle (woody material 0.25”—1.00” diameter) FMC trended positively through the season.

Preliminary analysis of live FMC shows differences in FMC with needle age (Figure 3). From this preliminary analysis, there does not appear to be any statistical differences between sites; however, only one-third of the data has been processed in the lab.

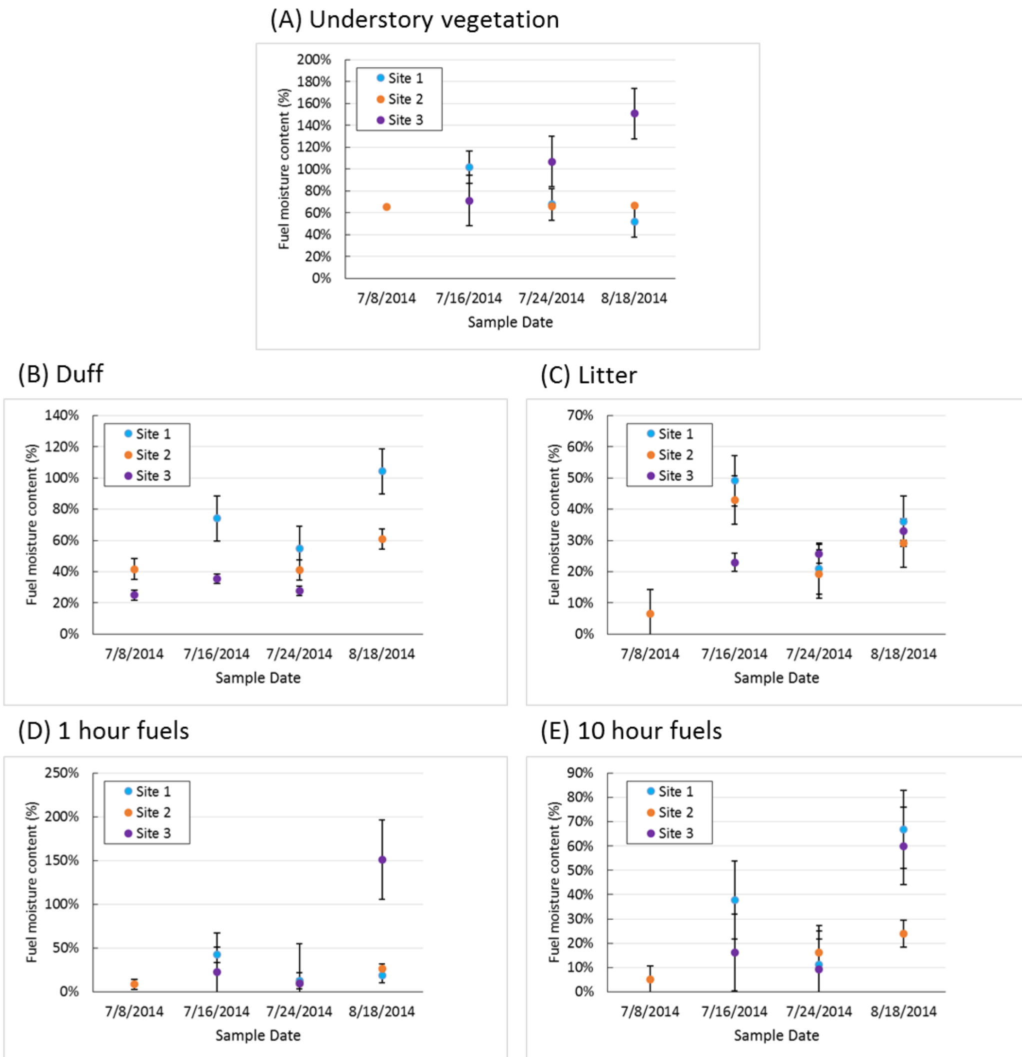

Figure 2. Mean (±1 Standard Error) FMC for dead fuel particles.

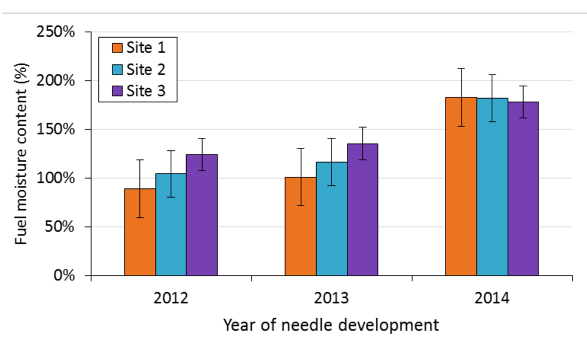

Figure 3. Mean live FMC on August 20—22 for each site by the year of needle development. Note: Results are preliminary and reflect approximately one-third of the data collected.

Stand structure across three stages of forest development

Tree density significantly differed between mature forest with high canopy cover, mature forest with moderate canopy cover, and the young post-fire forest. Sapling density, sapling basal area, total basal area, and all measures of quadratic mean diameter did not differ between the two mature study sites but did differ between the young, post-fire site and the two mature sites (Table 1). This data will be further analyzed and FMC models will be implemented during the next year.

Table 1. Mean and 95% confidence intervals for a selection of forest structure by site

Stand Structure Attribute	Site 1: Mature forest with moderate canopy cover	Site 2: Mature forest with high canopy cover	Site 3: 25 year old post-fire forest
Tree density (ha^{-1})	725 (627-822)	1300 (1099-1500)	0 (0)
Tree basal area (m^2)	40 (34.5-45.5)	46.9 (38.9-54.8)	0 (0)
Tree quadratic mean diameter (cm)	25.8 (24.1-27.6)	23.1 (21.5-24.7)	0 (0)
Sapling density (ha^{-1})	2274 (1792-2755)	1991 (1417-2565)	7417 (5896-8938)
Sapling basal area (m^2)	2.1 (1.6-2.7)	2.8 (1.9-3.6)	13.3 (10.4-16.2)
Sapling quadratic mean diameter (cm)	3.0 (2.6-3.4)	4.0 (3.4-4.6)	5.2 (4.5-6.0)
Total basal area (m^2)	42.1 (36.7-47.6)	49.6 (41.5-57.7)	13.1 (10.4-16.2)
All quadratic mean diameter (cm)	14.7 (13.1-16.2)	15.4 (14.0-16.7)	5.2 (4.5-6.0)
Seedling density (ha^{-1})	11341 (7812-14871)	6343 (3614-9072)	8980 (5824-12135)

The density of seedlings, saplings, and trees varied by species and site (Table 2). Mature lodgepole pine (*Pinus contorta*) tree density was highest in the high canopy cover site and lowest in the young, post-fire forest site. Lodgpeole pine seedlings were highest on the moderate canopy cover site that was affected by the mountain pine beetle and lowest on the high canopy cover site. Subalpine fir (*Abies lasiocarpa*) trees and saplings were most dense on the moderate canopy cover site and absent from the post-fire site. Subalpine seedlings were highest on the high canopy cover site and decreased with reductions in canopy cover. White bark pine (*Pinus albicaulis*) trees were the same in both mature forest stands but were absent from the post-fire stand. Whitebark pine saplings and seedling density were highest on the moderate canopy cover site and lowest on the post-fire site. Englemann spruce (*Picea Englemannii*) tree, sapling, and seedling density was highest on the high canopy cover site and lowest on the post-fire site.

Table 2. Species specific stand structure by site

Site	Species	Tree density (ha^{-1})	Sapling density (ha^{-1})	Seedling density (ha^{-1})	Basal area (ha^{-1})
1—Mature, moderate canopy cover	*Abies lasiocarpa*	68.1±24.8	355.8±149.8	732.2±247.3	2.3±0.9
	Pinus albicaulis	5.6±4.1	714.6±143.1	1092.9±255.8	0.6±0.1
	Pinus contorta	619.6±58.3	1157.9±282.1	9354.5±2877.9	38.8±2.5
	Picea englmannii	37.5±11.3	57.4±27.2	278.9±125.9	0.9±0.3
2—Mature, high canopy cover	*Abies lasiocarpa*	67.4±25.4	279±116.4	1180.9±353.6	2±0.7
	Pinus albicaulis	5.6±5.6	214.1±63.9	512.2±106.1	0.3±0.1
	Pinus contorta	1101.1±203.5	1329.9±303	4329.5±2385.6	41.3±5.7
	Picea englmannii	125.5±37.6	168.2±54.3	320.9±111.3	6±2.2
3—young, post-fire low canopy cover	*Abies lasiocarpa*	0±0	0±0	7.6±5.2	0±0
	Pinus albicaulis	0±0	0±0	22.9±13.6	0±0
	Pinus contorta	0±0	7417.2±969.9	8934±2633.8	13.3±1.5
	Picea englmannii	0±0	0±0	15.3±6.9	0±0

The growth rate of seedlings and saplings varied with site (Figure 3). Linear models were fit for each site. The highest growth rate (~0.3 m yr^{-1}) occurred on the post-fire site with no surviving overstory trees (R^2=0.62, $p<0.001$). Mature forest were significantly lower than the post-fire stand. The mature forest site with moderate canopy cover had a growth rate of ~0.03 m yr^{-1} (R^2 = 0.53, $p<0.001$) and the high canopy cover site had a growth rate of ~0.02 m yr^{-1} (R^2 = 0.35, $p<0.001$).

✦ PRODUCTS

Senior thesis (independent study research paper): Erick Larsen. 2014. Drivers of tree regeneration and seedling success in Yellowstone National Park. University of Washington.