

**FRASER TSA SPRUCE
FOLIAR SAMPLING AND
ANALYSIS IN THE
MASELPANIK CREEK
DRAINAGE**

**MINISTRY
CONTRACT/FILE:
CS17LMN001**

Submitted by:

Ben Andrew and Jeff McWilliams
B.A. Blackwell and Associates Ltd.
270-18 Gostick Place
North Vancouver, B.C.
V7M 3G3

Submitted to:

Ann Wong
Stewardship Forester
MOFLNRO, DCK
Phone: 604-702-5700

March, 2017



**B.A. Blackwell
& Associates Ltd.**

Contents

1	Introduction	3
2	Methods	3
	Study Area and Site Description	3
	Sampling Methods.....	5
	Sample Preparation.....	5
3	Results and Discussion.....	6
	Macronutrients: N, P, Ca, Mg, K, and S	8
	Micronutrients: Cu, Zn, Mn, Fe, B, and SO ₄	8
	Foliar Nutrient Ratios: N:P, N:K, N:Mg, and N:S	9
4	Recommendations.....	9
	References	11
	Appendix A - Raw Data and Interpretations	13

List of Figures

Figure 1. Foliar Analysis Transects Locations.....	4
--	---

List of Tables

Table 1. Site and Stand Characteristics for Transects.....	7
Table 2. Foliar Nutrient Status and Average Foliar Macronutrient Concentration for N, P, Ca, Mg, K, and S.....	8
Table 3. Foliar Nutrient Status and Average Foliar Micronutrient Concentration for Cu, Zn, Mn, Fe, B, and SO ₄	9
Table 4. Foliar Nutrient Ratios for N:P, N:K, N:Mg, and N:S.....	9

1 INTRODUCTION

B.A. Blackwell & Associates Ltd. was contracted by the Chilliwack Forest District to conduct foliar sampling on young spruce hybrid (Sx)¹ plantations in the Maselpanik drainage near Hope, British Columbia. The objective of the foliar sampling is to gather data to determine if re-fertilization of stands is supported by foliar micro- and macronutrient concentrations.

Research in BC and elsewhere in the world has shown that repeated fertilization of spruce can result in significant increases in growth and volume (Brockley 2004, 2010, Bergh *et al.* 2005). Determining if the nutritional status of stands can be improved by fertilization is important to guide fertilization planning for young spruce leading plantations. Foliar samples were analyzed for concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), boron (B), total sulfur (S), and inorganic sulfate-sulphur (SO₄).

2 METHODS

Study Area and Site Description

The study area is accessed using the Silver Skagit Rd, 2 km east of Hope BC. The foliar sampling sites are located adjacent to the Maselpanik Forest Service Road (FSR), which is located 33 km south of the Silver Skagit turnoff (Figure 1).

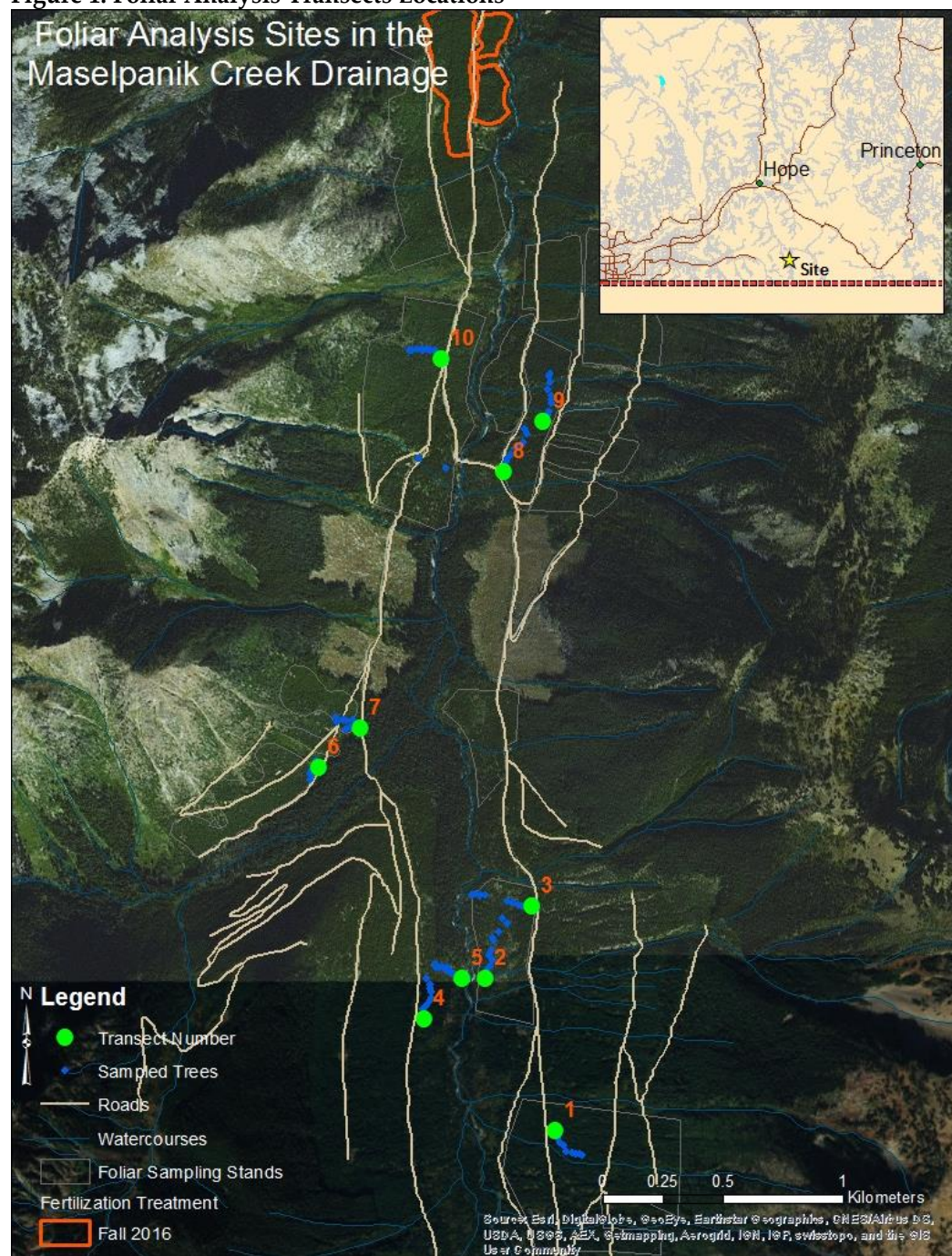
The study area located in the Coastal Western Hemlock Southern Moist Submaritime variant (CWHms1) but is transitional to the Mountain Hemlock Leeward Moist Maritime variant (MHmm2) biogeoclimatic unit. The climate in the CWHms1 is transition between the coast and interior. It is characterized by cool dry summers and moist cool winters (Green and Klinka 1994).

Reconnaissance field work to identify transect locations was conducted by Jeff McWilliams and Aaron Bigsby. Transects were located primarily on 01 (HwBa - Step Moss) site sites, with minor components of 04 (BaCw - Oak Fern) and 05 (HwBa - Queen's Cup). Transects were located on areas that were generally mesic to hygric and had nutrient regimes from medium to medium rich. Stands were mixes of Sx (planted) and Ambies amabilis (advanced regeneration) resulting from clearcut logging about 1980. Sx ages on transects were between 33 to 35 years old. Transects 6 and 7 had been aerially fertilized with Urea at 435kg per hectare in fall 2008.

¹ In the eastern portion of the Fraser TSA the ranges of white (Sw) and Engelmann (Se) spruce overlap and where this occurs intermediate forms between the two species can be found. Spruce that cannot be clearly assigned to either species should be referred to as hybrids (Sx) (Native Trees of Canada, R.C. Hosie, 1979). Within this report all spruce will be assumed to be the hybrid.

The ten transects were identified in locations that avoided areas where road dust or other contaminants could affect sample analysis results. Transects were located in consideration of stand and ecological conditions that could increase variability in foliar nutrient concentrations. Where practicable, transects were established parallel to the contours and 200 m apart.

Figure 1. Foliar Analysis Transects Locations



Ecological information was collected at each transect including:

- soil moisture regime,
- soil nutrient regime,
- site index, age, height, dbh (on representative trees),
- forest health issues,
- site history, and
- stand origin.

Sampling Methods

Sampling was completed between November 17, 2016 and November 21st 2016. In total, ten sites were sampled along each transect and two trees were sampled at each site. A minimum of two branches per tree were collected (four branches at each site; 40 branches per transect). Sample sites were spaced approximately 10 m from each other.

Trees with health problems were avoided. Each tree was flagged, numbered with blue paint, and GPS'ed for future reference. Samples were collected from the current year's foliage in dominant or codominant trees between the upper half of the tree and below the top quarter. Two branch-ends per tree were collected consisting of the current year's terminal and one or two first order laterals by shooting down branches with a shotgun. These were put in bags and labelled with transect and site number. Individual foliage samples were kept cool (1 to 5 °C) until drying and processing was undertaken.

Sample Preparation

Samples were dried for up to two days at 70 °C during the day and 60 °C overnight until a constant weight was reached. Composite samples from current year's growth were prepared for each transect and were comprised of 4 grams of mixed dry foliage from each tree (2 g/branch) for a total of 80 g for all 20 trees for each site. The samples were sent to Pacific Soil Analysis, #5-11720 Voyageur Way, Richmond, BC for nutrient analysis.

3 RESULTS AND DISCUSSION

The objective of foliar nutrient analysis is to identify the current foliar nutrient concentrations and make recommendations regarding nutrient requirements for operational fertilization of the sampled stands and similar stands in the area.

Sampling for this study was conducted in the CWHms1, which is transitional between coastal and interior climates (Green and Klinka 1994). The interpretation of foliar nutrient concentrations used interpretative tables for spruce that are based on research conducted in the interior of BC (Brockley 2012). Despite the fact that the study area has a transitional climate, these tables provide the best available interpretive data for assessing spruce nutrient concentrations and identifying deficiencies. Site and stand characteristics for the transects are provided in Table 1.

All foliar nutrient interpretation classes are from New Tools for Interpreting Foliar Nutrient Status (Brockley 2012). Based on inter-laboratory comparisons between the Ministry of Environment (MoE) laboratory (Victoria, BC) and the Pacific Soil Analysis Inc. laboratory (Richmond, BC) completed by Brockley, foliar nutrient data was normalized using Brockley's Excel conversion table (2013). Pre- and post- normalization foliar nutrient concentrations and interpretations are shown in Appendix A. The following sections discuss the results of the average nutrient concentrations and ratios using the available interpretative tables (Brockley 2012).



Table 1. Site and Stand Characteristics for Transects.

Transect Number	BGC	Site Series	Aspect	Slope (%)	Stand Age	Species Mix	Disturbance History	Average Tree Height (m)	Average DBH (cm)	Crown Closure (%)
1	CWHms1	01(04,05)	W	30	35	Sx6Ba4	logged 80	11.5	17	35
2	CWHms1	01(04,05)	W	25	35	Sx6Ba4	logged 80	11.5	17	35
3	CWHms1	01(04,05)	W	25	35	Sx6Ba4	logged 80	11.5	17	35
4	CWHms1	01(04,05)	E	30	33	Sx6Ba4(Hm)	logged 80	11	16.5	35
5	CWHms1	01,04(05)	E	20	33	Sx5Ba5	logged 80	11.5	17	30
6	CWHms1	01(04,05)	SE	40	35	Sx8Ba2	logged 80; Fertilized fall 2008 (Urea)	12	17.5	35
7	CWHms1	01(04,05)	SE	40	35	Sx8Ba2	logged 80; Fertilized fall 2008 (Urea)	12	17.5	35
8	CWHms1	01(04,05)	W	25	33	Sx6Ba4	logged 80	11.5	17	35
9	CWHms1	01(04,05)	W	30	33	Sx6Ba4	logged 80	11.5	17	35
10	CWHms1	01(04)	E	45	35	Sx6Ba4	logged 80	13	18.5	35

Macronutrients: N, P, Ca, Mg, K, and S

Concentration for macronutrients are reported as the percent concentration by dry weight. N foliar concentrations for four sites were severely deficient ($< 0.9\%$) and six sites were moderately to severely deficient (0.90 to 1.10%; Table 2). The average foliar N concentration was moderately to severely deficient for all transects (0.94%), which is within the range of reported values in BC of 0.9 to 1.17% (Brockley and Simpson 2004, Wang and Klinka 1997).

Table 2. Foliar Nutrient Status and Average Foliar Macronutrient Concentration for N, P, Ca, Mg, K, and S.

Nutrient	Average %	Status
N	0.94	Moderately to severely deficient
P	0.15	Adequate
Ca	0.53	Adequate
Mg	0.10	Adequate
K	0.57	Adequate
S	0.08	Slightly to moderately deficient

Based on research showing improved growth response to multiple fertilization applications and the moderate to severe deficiency measured in this study, a positive response to fertilization with N should be realized. Foliar N concentrations in spruce below 1.1% are a good indicator of potential response to fertilization with N, and basal area increases on the average of 42% have been observed (Brockley 2000a, 2012).

Average nutrient concentrations for P, Ca, Mg, and K were all found to be adequate (Table 2). P was slightly to moderately deficient on six of the ten sites and K was slightly to moderately deficient on one site.

Sulfur was slightly to moderately deficient on all transects with an average concentration of 0.08% (Table 2). Sulphate-sulphur (SO_4) ppm and N:S ratios are better indicators of deficiencies than S foliar nutrient concentrations and should be relied upon more for interpreting deficiencies. The average N:S ratio and SO_4 ppm did not identify S deficiencies and are discussed further below.

Micronutrients: Cu, Zn, Mn, Fe, B, and SO_4

Cu, Zn, and Mn were not deficient on any transect (5, 48, and 687 parts per million (ppm) respectively; Table 3). Fe is possibly deficient on half the sites and the other half have probable deficiencies, and the average foliar nutrient concentration was possibly deficient (21 ppm). At levels where possible Fe deficiencies exist, the growth response after N fertilization is still likely to be positive (Brockley 2012).

Boron was possibly deficient on seven transects as was the average concentration of 11 ppm. 3 Sites had foliar B concentrations below 10 ppm, which may limit growth response to fertilization (Brockley 2006). The average concentration of 11 ppm found in this study indicates that a fertilizer induced deficiency is possible (Brockley 2012).

Trials have shown that fertilization with N or with an N and S blend can cause B deficiencies (Brockley 2006). The induced deficiencies may cause top dieback or decreased height growth (Brockley 1996, 2003, 2012; Stone 1990).). However, Brockley has suggested that unless B is less than 6 ppm, induced B deficiencies in spruce are unlikely (Brockley 2017 pers. comm.).

Sulphate-sulphur was adequate on all transect with an average of 139 ppm (Table 3). SO₄ is a useful indicator, as it represents excess S not required to balance the constant ratio between N and organic S (Brockley 2012; Kelly and Lambert 1972). As the SO₄ concentrations in the foliar samples collected in this study are relatively high for spruce, induced S deficiencies are less likely despite the indication of S that foliage might be slightly to moderately deficient. Research on lodgepole pine indicates that high SO₄ concentrations are a strong indicator, assuming no other limiting deficiencies are present, that fertilization with N will result in a significant basal area response in trees (Brockley 2000b).

Table 3. Foliar Nutrient Status and Average Foliar Micronutrient Concentration for Cu, Zn, Mn, Fe, B, and SO₄

Nutrient	Average ppm	Status
Cu	5	No deficiency
Zn	48	No deficiency
Mn	687	No deficiency
Fe	21	Possible deficiency
B	11	Possible deficiency
SO ₄	139	Adequate

Foliar Nutrient Ratios: N:P, N:K, N:Mg, and N:S

No transect had nutrient ratios that were deficient (Table 4). While the N:S ratio is not deficient, Brockley (2012) suggests that S deficiency will likely be induced if the N:S ratio is > 13. However, given the high SO₄ concentrations, it unlikely that an induced S deficiency will result from N fertilization (Brockley pers. comm. 2017).

Table 4. Foliar Nutrient Ratios for N:P, N:K, N:Mg, and N:S.

Nutrient	Average ratio	Status
N:P	6	No deficiency
N:K	1.7	No deficiency
N:Mg	9	No deficiency
N:S	12	No deficiency

4 RECOMMENDATIONS

The results of this study indicate severe and moderate to severe N deficiencies on all transects and possibly inducible B deficiencies. To address the N deficiency, fertilization with urea is recommended.



While boron induced deficiencies are possible, the boron concentrations are not below 6 ppm, so an induced deficiency is not anticipated. The N:S ratio is 12, which is less than the 13 or greater ratio that indicates that an S deficiency may be induced by fertilization. Brockley (2004) reported that fertilization could induce S deficiencies and result in smaller growth responses, and also indicated that with multiple fertilizations the frequency of induced S deficiency may increase. However, as foliar sulphate levels are adequate, an induced S deficiency is not anticipated (Brockley pers. comm. 2017). Care should be taken to avoid inducing B and S deficiencies as a result of multiple applications of fertilizer. Monitoring of foliar nutrient concentrations following subsequent fertilization of sites 6 and 7 (previously fertilized sites) is recommended to identify effects on B and S concentrations.

REFERENCES

- Bergh, J., Linder, S., and Bergstrom, J. 2005. Potential production of Norway spruce in Sweden. *For. Ecol. Manag.* 204(1): 1–10.
- Brockley, R.P. 1996. Lodgepole Pine Nutrition and Fertilization: a Summary of B.C. Ministry of Forests Research Results. B.C. Ministry of Forests, Victoria. *For. Resour. Dev. Agree. Rep.* 266.
- Brockley, R.P. 2000a. Using foliar nutrient levels to predict lodgepole pine fertilization response. Ministry of Forests, Victoria, B.C. *Ext. Note* 44.
- Brockley, R.P. 2000b. Using foliar variables to predict the response of lodgepole pine to nitrogen and sulphur fertilization. *Can. J. For. Res.* 30: 1389-1399.
- Brockley, R.P. 2003. Effects of nitrogen and boron fertilization on foliar boron nutrition and growth in two different lodgepole pine ecosystems. *Can. J. For. Res.* 33: 988–996.
- Brockley, R.P. 2004. Effects of different sources and rates of sulphur on the growth and foliar nutrition of nitrogen-fertilized lodgepole pine. *Can. J. For. Res.* 34: 728-743.
- Brockley, R.P. and D.G. Simpson. 2004. Effects of intensive fertilization on the foliar nutrition and growth of young lodgepole pine and spruce forests in the interior of British Columbia. (E.P. 886.13): establishment and progress report. B.C. Min. For., Res. Br., Victoria, B.C. *Tech. Rep.* 018. <<http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr018.htm>.
- Brockley, R.P. 2006. Fertilizing Interior Forests: the scientific basis (and some informed speculation). Prince George Fertilization Workshop. [http://www.for.gov.bc.ca/ftp/hfp/external!/publish/fft_standards_on_cms_web/Fertilization/related-docs-websites/Prince%20George%20fertilization%20workshop%20\(Brockley%20Feb%2006\).ppt](http://www.for.gov.bc.ca/ftp/hfp/external!/publish/fft_standards_on_cms_web/Fertilization/related-docs-websites/Prince%20George%20fertilization%20workshop%20(Brockley%20Feb%2006).ppt).
- Brockley, R.P. 2010. Effects of repeated fertilization in a young spruce stand in central British Columbia. *Can. J. For. Res.* 40: 1687–1697 (2010).
- Brockley, R.P. 2012. New Tools for Interpreting Foliar Nutrient Status. Contract Research Report to Forest Practices Branch, Ministry of Forests, Lands, and Natural Resource Operations. Contract OT12FHQ299.
- Brockley, R.P. 2013. Foliar Data Normalization Spreadsheet. http://www.env.gov.bc.ca/esd/distdata/ecosystems/TEI/TEI_Data/.
- Green, R.N. and K. Klinka. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. Res. Br., B.C. Min. For., Victoria, B.C. *Land Manage. Handb.* No. 28.

Kelly, J., and M. J. Lambert. 1972. The relationship between sulphur and nitrogen in the foliage of *Pinus radiata*. *Plant Soil* 37:395-408.

Stone, E.L. 1990. Boron deficiency and excess in forest trees: A review. *For. Eco. And Man.* 37:49-75.

Swift, K.I. and R.P. Brockley. 1994. Evaluating the nutrient status and fertilization response potential of planted spruce in the interior of British Columbia. *Can. J. For. Res.* 24:594–60202.

Wang , G.G., and K. Klinka. 1997. White spruce foliar nutrient concentrations in relation to tree growth and soil nutrient amounts. *For. Eco. Man.* 98:89-99.

APPENDIX A - RAW DATA AND INTERPRETATIONS

Table 1.1. Legend for Nutrient Interpretations (Brockley 2012).

Macronutrients			
Severely deficient	Moderately to severely deficient	Slightly to moderately deficient	Adequate
Micronutrients and SO ₄			
Severely deficient	Probable deficiency	Possible deficiency	No deficiency

Table 1.2. Normalized Foliar Nutrient Concentrations and Interpretations for Spruce Samples

Macronutrient Concentration	Transect										Average	Standard Deviation
	1	2	3	4	5	6	7	8	9	10		
N (%)	1.05	0.79	0.88	1.03	0.96	0.86	0.86	1.05	1.01	0.92	0.94	0.09
P (%)	0.16	0.13	0.14	0.14	0.14	0.13	0.13	0.19	0.17	0.17	0.15	0.02
K (%)	0.59	0.55	0.61	0.55	0.63	0.63	0.49	0.53	0.59	0.55	0.57	0.04
Ca (%)	0.64	0.36	0.48	0.51	0.38	0.55	0.78	0.59	0.53	0.51	0.53	0.11
Mg (%)	0.11	0.09	0.10	0.08	0.09	0.09	0.11	0.12	0.11	0.11	0.10	0.01
S (%)	0.09	0.08	0.08	0.09	0.09	0.07	0.08	0.09	0.08	0.08	0.08	0.01
Micronutrient Concentration												
SO ₄ (ppm)	116.67	188.89	138.89	105.56	122.22	161.11	122.22	177.78	127.78	127.78	139	26
B (ppm)	11.40	11.40	12.28	13.16	10.53	10.53	13.16	8.33	8.77	6.75	11	2.0
Cu (ppm)	4.50	3.00	4.00	5.00	5.00	5.50	5.50	5.00	5.50	4.50	5	0.8
Zn (ppm)	62.50	40.50	45.00	46.50	45.50	49.50	44.50	49.50	54.50	42.00	48	6.2
Fe (ppm)	28.69	17.22	17.22	22.95	22.95	17.22	28.69	17.22	11.48	22.95	21	5.3
Mn (ppm)	825.00	682.50	521.25	510.00	543.75	663.75	693.75	772.50	836.25	817.50	687	121

Table 1.3. Normalized Foliar Nutrient Concentrations Ratios and Interpretations for Spruce Samples (no deficiencies identified).

Nutrient Ratios	Transect										Average	Standard Deviation
	1	2	3	4	5	6	7	8	9	10		
N:S	12	10	11	12	11	12	12	12	13	12	12	0.79
N:P	7	6	6	8	7	7	7	6	6	5	6	0.61
N:K	1.79	1.44	1.46	1.89	1.53	1.38	1.77	1.99	1.73	1.68	1.7	0.20
N:Mg	9.42	8.36	8.65	12.20	10.82	9.16	7.87	9.11	8.93	8.39	9	1.23

Table 1.4. 100 Needle Weights for each Transect and Averages.

100 Needle Weight	Transect										Average	Standard Deviation
	1	2	3	4	5	6	7	8	9	10		
gm	0.722	0.787	0.845	0.632	0.788	0.778	0.805	0.776	0.802	1.013		0.091
gm	0.716	0.801	0.869	0.686	0.811	0.791	0.813	0.742	0.789	1.075		0.102
gm	0.719	0.779	0.889	0.63	0.802	0.796	0.802	0.72	0.798	1.115		0.122
Average	0.719	0.789	0.868	0.649	0.800	0.788	0.807	0.746	0.796	1.068	0.803	

Table 1.4. Pacific Soils Foliar Nutrient Concentrations for Spruce Samples (not Normalized).

	Transect									
Macronutrient Concentration	1	2	3	4	5	6	7	8	9	10
N (%)	1.05	0.79	0.88	1.03	0.96	0.86	0.86	1.05	1.01	0.92
P (%)	0.17	0.13	0.15	0.14	0.15	0.13	0.13	0.20	0.18	0.18
K (%)	0.62	0.58	0.64	0.58	0.66	0.66	0.53	0.56	0.62	0.58
Ca (%)	0.66	0.41	0.53	0.54	0.43	0.58	0.77	0.62	0.56	0.54
Mg (%)	0.109	0.092	0.099	0.083	0.086	0.092	0.107	0.113	0.111	0.107
S (%)	0.086	0.080	0.081	0.088	0.085	0.073	0.075	0.089	0.078	0.077
Micronutrient Concentration										
SO ₄ (ppm)	117	189	139	106	122	161	122	178	128	128
B (ppm)	11	11	12	13	11	11	13	8	9	7
Cu (ppm)	5	3	4	5	5	6	6	5	6	5
Zn (ppm)	63	41	45	47	46	50	45	50	55	42
Fe (ppm)	25	15	15	20	20	15	25	15	10	20
Mn (ppm)	825	683	521	510	544	664	694	773	836	818