The Shaping of Soil Characteristics by Variation in Dominant Tree Species

BIOS 569 – Practicum in Environmental Field Ecology

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Abstract

This paper reports on a study carried out to investigate the influence of boreal forest tree species on soil characteristics within a stand. Five species of trees were analyzed; two early (red pine and trembling aspen), two late (sugar maple and hemlock) and one intermediate successional species (balsam fir). At all stand types studied, species had an effect on all factors examined. A significant difference was observed in soil bulk density, canopy cover, humus depth, and percent moisture content between the species studied. The early successional species had significantly thinner humus layers than that of the other species. In addition, the early successional species had lower average canopy cover measurements than those of the late successional species. Contrasting with these findings, the early successional species had the two highest average bulk density values of the five species studied. The significant relationship found for several of the factors researched suggests that the different tree species affect soil characteristics within the area they occupy. Further analysis over time may yield information that would show the effects of dominant tree species on the evolution and variation seen among soils of different stands.

Introduction

Thin, well drained soils are common in the boreal forests of the North Central United States. In addition, a short growing season and cold conditions, paired with the presence of conifers, facilitate acidic soil content and generally poor growing conditions (Klyza 1994). The geology of an area forms many of the base characteristics of these forest stands; however, the dominant species in a stand can shape much of the physical and chemical characteristics of the soil below (Ovington 1956). In general, hardwood forests take up more nutrients and return a greater amount of the nutrients as leaf litter than coniferous species. This study tested which effects tree stands of different dominant species have on soil characteristics.

The study examined the soil characteristics of five different dominant tree stand types present on the property: balsam fir (*Abies balsamea*), sugar maple (*Acer saccharum*), red pine (*Pinus resinosa*), trembling aspen (*Populus tremuloides*), and hemlock (*Tsuga canadensis*).

Trembling or "quaking" aspen is an early successional species, usually found in areas of recent disturbance. The species is not tolerant of shade and grows very quickly with adequate sunlight and nutrients. Trembling aspen-dominated stands will usually succeed to either a northern hardwood forest or conifer forest, depending on the location. Balsam fir is a short-lived, shade tolerant tree species often found in disturbed areas of forests. Sugar maple is a shade tolerant, long-lived species that dominates many mesic deciduous forests. Red pine is a shade intolerant, fast growing species dependent on fire for establishment. Hemlock is a shade tolerant, slow growing tree species usually associated with late successional forests (Burton and Wagner 2002).

Earlier investigations have indicated that soil characteristics are modified by the tree species present. This paper reports on an evaluation of the effects of species in relation to the soil within five stands of differing dominant tree species. The analysis includes soil bulk density, pH, moisture content, overstory density, and humus and B horizon depth measurements. Nearly all of the factors are affected differently by each of the individual species.

Methods

Sites were selected from the University of Notre Environmental Research Property; Land O' Lakes, WI. Fifteen dry, upland tree stands were measured; each with an average diameter at breast height (DBH) of greater than 10 cm (Fig. 1). Each site was randomly selected within each stand. A circular, 5 meter radius survey was taken around each site to assess the species composition and makeup of the site. The DBH values were taken using a Ben Meadows Company DBH tape measure. There were three replicates for each of the five dominant species; defined as consisting of at least 75% of the organisms greater than 10 cm DBH.

Forest overstory density measurements were taken using a Model-C

Spherical Densiometer (Forest Densiometers). The temperature of the soil at 12 cm was recorded for all sites in a two hour period using a digital probe.

In order to make accurate comparisons between the stands, the leaf litter was carefully removed and a new zero level was established beneath at the humus level (Ovington. 1953). Two soil samples were taken from each site; at depths of 0-5 cm and 10-15 cm. All samples were taken within a three hour period to minimize potential change in any of the characteristics that may occur over time. The soil samples were collected in Ziploc bags to retain moisture and reduce possible contamination. Prior to analysis, each of the samples were homogenized and rocky and organic material removed.

Moisture Content

The moisture content of each soil depth was taken using an Oven Drying Method. Sub samples of the collected soil were massed (approximately 20 grams) and placed on coffee filters. The samples were then placed in a drying oven at 50º C for 30 hours. The dry samples were then massed.

pH

The pH at each depth of soil was taken using a 1:1 ratio method. Air-dried, sifted soil samples of 10 grams were mixed with 10 mL of distilled water. The soil/water mixture was then manually shaken for one minute. The mixture was then allowed to settle to a supernatant for three minutes. A Hanna Instruments digital pH meter was used to measure the mixture.

Soil Bulk Density

Soil bulk density was determined using standard methods. A single soil sample from each site was taken and the volume of the soil removed was measured with a graduated cylinder and water. The soil was then air dried and massed.

Results

An analysis of variance (ANOVA) was run for each of the factors measured. The ANOVA for species and canopy cover was significant with a p value of 0.000. The pairwise comparison probabilities for species and canopy cover are displayed in Table 1. The ANOVA for species and bulk density was significant with a p value of 0.039. The pairwise comparison probabilities for species and soil bulk density are displayed in Table 2. The ANOVA for species and humus depth was significant with a p value of 0.008. The pairwise comparison probabilities for species and humus depth are seen in Table 3. The ANOVA for species and B Horizon depth was not significant with a p value of 0.088. The ANOVA for species and Basal Area was not significant with a p value of 0.111.

Two-way ANOVA's were run with the sites (species) and depths as factors. For the ANOVA for moisture content, the species and depths were significantly different with p values of 0.011 and 0.001, respectively. However, the interaction was not significant with a p value of 0.234. For the two-way

ANOVA of pH, the species, depths and interaction were not significant with p values of 0.276, 0.176, and 0.763.

Discussion

From the results, there is a significant relationship between dominant tree species and soil characteristics. The evaluation of canopy cover (null hypothesis: species has no effect on canopy cover) shows that the different tree species create different patterns of sunlight on the soil surface. The sugar maple and hemlock stands, both highly shade tolerant species show the highest average canopy cover percentages, while the trembling aspen stands present the lowest canopy cover percentages (Fig. 2). The sugar maple stands had a significantly higher canopy cover percentage than all but the hemlock stands. In addition, trembling aspen had a significantly lower canopy cover percentage than all other species (Table 1). The statistics correlate with the information regarding shade tolerance amongst the tree species involved in the study.

The analysis of the humus depth showed a great deal of variation between the species (null hypothesis: species has no effect on humus depth). The early-successional species (red pine and trembling aspen) show a much shallower humus layer in comparison with the other species in the study (Fig. 3). Both the red pine and trembling aspen were significantly different than the other species in the study, although they were not significantly different from each other (Table 2). The thin humus layer may be due to a more recent disturbance, allowing for less accumulation of organic material. Another possible explanation is simply that less organic material is released every year, or the decomposition rate of the litter is much greater than the other species. The fact that none of the other species differs from one another suggests that a primary factor in the development of humus is dependent on the classification of a species as an early or late successional species.

An examination of the B horizon statistics yields less definitive information. A one way ANOVA (null hypothesis: species has no effect on B horizon depth) shows that the data collected for the species are not significantly different from one another. The hemlock stands showed the greatest average B horizon depth, while sugar maple yielded the lowest average depth, however the analysis was not significant. This result may mean that the structural or chemical characteristics of the soil have a greater effect on the depth that minerals and ions are leached than that of the dominant species.

The analysis of the basal area data shows that most of the plots had trees of relatively similar age; assuming DBH as a surrogate of age within the same species and stand. The balsam fir and trembling aspen showed the lowest values, most likely due to the structure and growth of each species (Fig.5).

The consideration of the bulk density data shows that species does have a statistically significant relationship with soil bulk density within a stand (null hypothesis: species has no effect on soil bulk density). The soil bulk density of balsam fir is significantly different than all other species except hemlock (Table 1). It is interesting to note that the species displaying the lowest bulk densities were both shade-tolerant coniferous trees (Figure 6). In addition, the species with the highest average bulk density were both of the early successional species (red pine and trembling aspen). One might infer that soil bulk density may decrease with the age of the stand.

The analysis of soil pH for each of the sites at both depths did not yield a significant difference between neither the species nor depths (null hypothesis: species has no effect on pH and depth has no effect on pH). The lack of difference between the species may be due to the depths at which measurements were taken. Figure 7 shows much greater differences between species pH at the 0-5 cm depth, likely due to the high proportion of organic material present at the surface as humus in all stands. The lower variation seen in the 10-15 cm depth sample may be due to the leaching of related amounts of minerals and ions to a similar depth in each of the different stands.

The results for moisture content percent show a lot of variation amongst the species and a steady trend for the two depths. For each species, the 0-5 cm depth yielded a higher moisture content percentage (Fig. 8). Red pine is significantly different than all other species in the study (Table 4). The lower moisture content of the red pine soil could explain the presence of the species. Red pine grows best in light, well-drained soils that are relatively low in nutrients

(Burton and Wagner 2002). Once again, the proportion of organic material in the form of humus is a likely explanation for the difference seen between the depths. Organic material holds more water and moisture than inorganic soil material does and this is reflected in the higher moisture content present in the 0-5 cm depth. The difference between the species may also be due to the amount of humus present coupled with the bulk density. The greatest humus depth was seen in hemlock and sugar maple; showing a relationship, at least in the case of hemlock. The amount of loose leaf litter was not measured in this study, but may play a factor in the amount of moisture present in the different soil samples.

This study has shown that, at the very least, the dominant species in a stand influences physical characteristics of the soil (moisture content, soil bulk density, humus depth, B horizon depth, and canopy cover). Under further investigation, additional factors may be found to differ significantly between the tree stands. Chemical analysis, such as the amount of nitrates, phosphorus, or other essential ions may differ significantly amongst tree stands dominated by different species. Another useful study may be to compare soil horizons for different tree stands rather than discrete depths. As more information on the evolution of soil characteristics within a tree stand is collected, a more complete picture of forest succession may be achieved.

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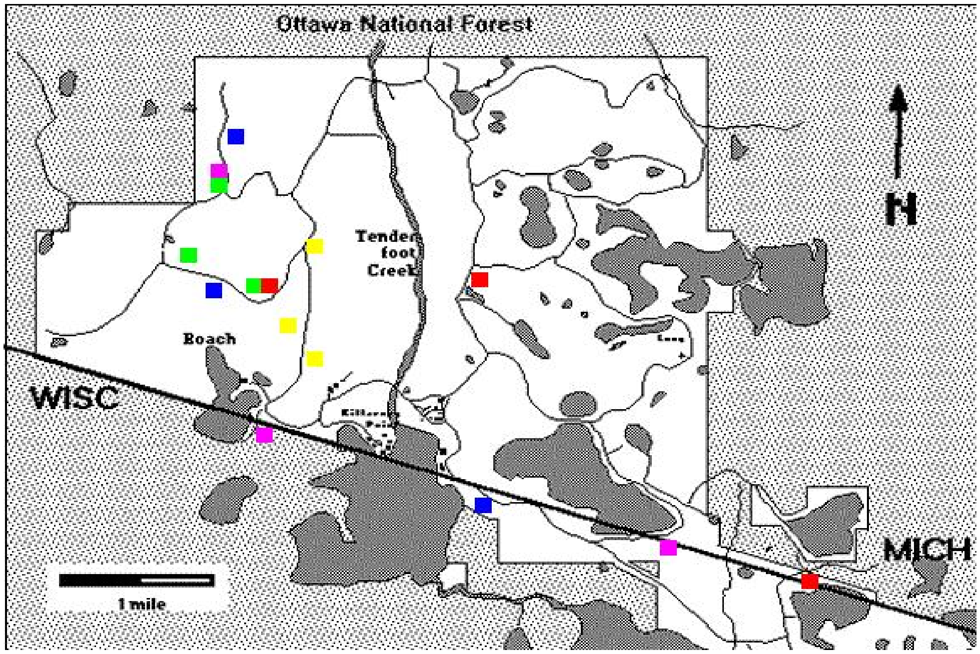
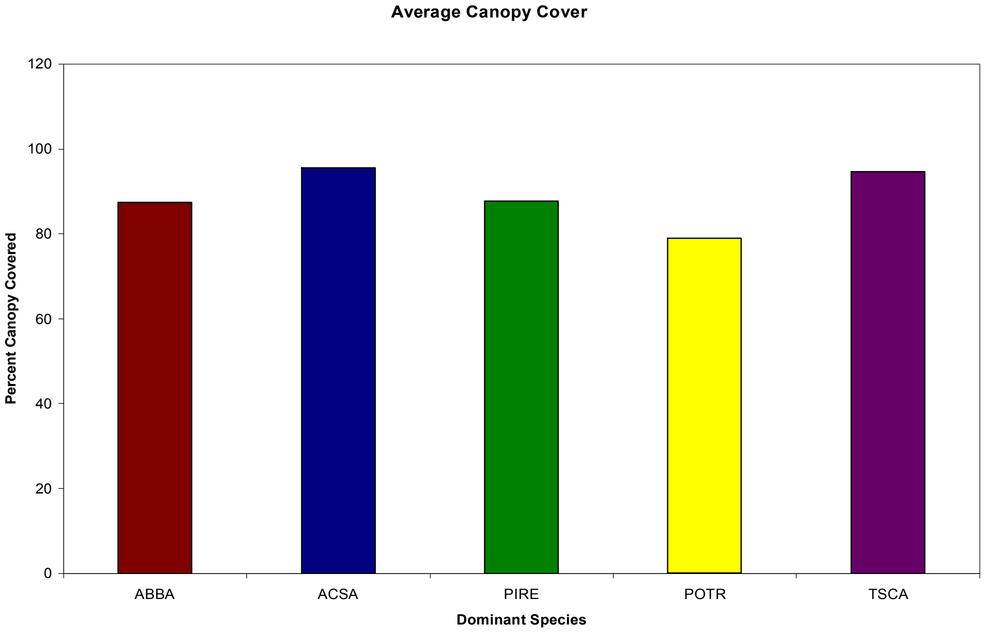


Fig. 1: Site locations. Balsam fir (ABBA)-red, sugar maple (ASCA)-blue, red pine (PIRE)-green, trembling aspen (POTR)-yellow, and hemlock (TSCA)-pink.



Fig

Fig. 2: The canopy cover averaged over the three sites per species (measured with a densitometer).

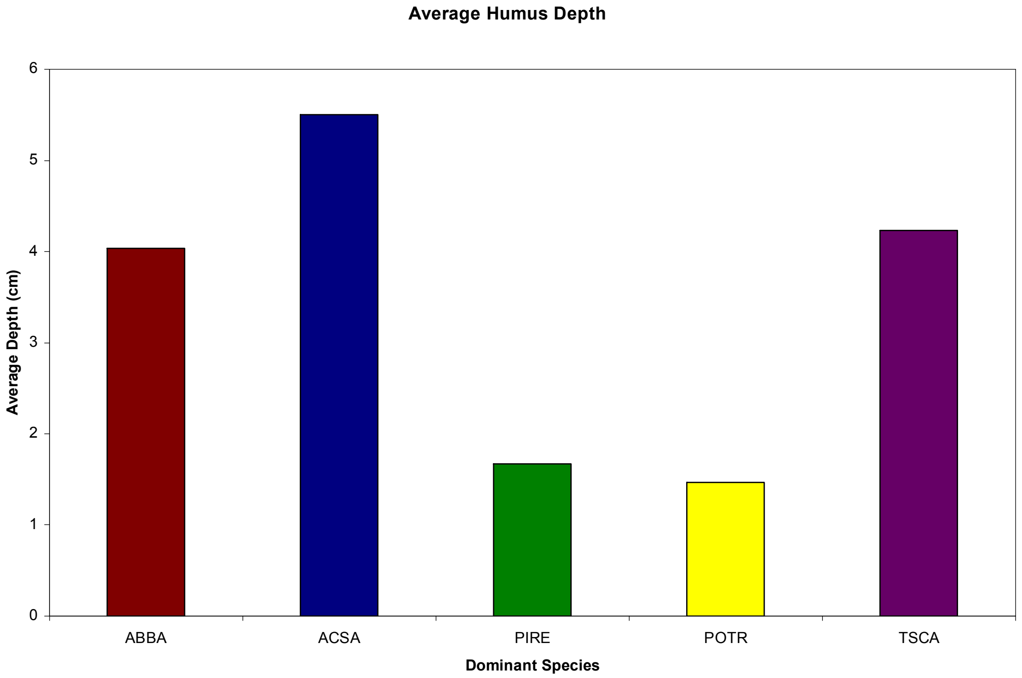


Fig. 3: The humus depth, averaged for each species over the three sites.

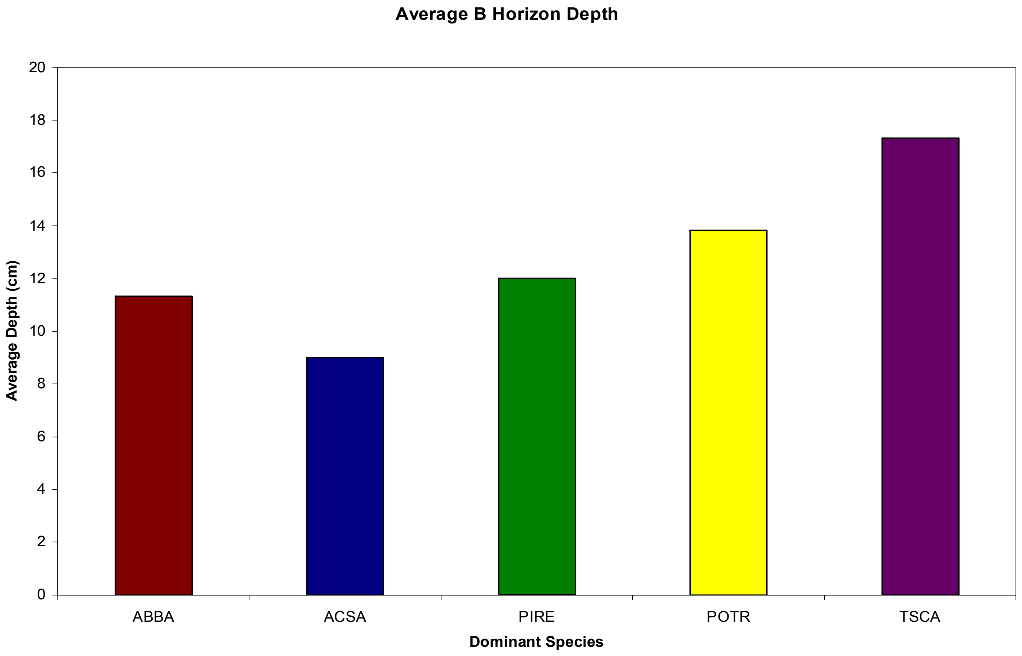


Fig. 4: The B Horizon depth, averaged for each species over the three sites.

	ABBA	ACSA	PIRE	POTR	TSCA
ABBA	1				
ACSA	0.001	1			
PIRE	0.818	0.002	1		
POTR	0.007	0.000	0.005	1	
TSCA	0.003	0.576	0.005	0.000	1

Table 1: Pairwise comparison probabilities (Fisher's LSD Test) for Canopy Cover. Balsam Fir=ABBA, ACSA=Sugar Maple, PIRE=Red Pine, POTR=Trembling Aspen and TSCA=Hemlock.

	ABBA	ACSA	PIRE	POTR	TSCA
ABBA	1				
ACSA	0.029	1			
PIRE	0.012	0.620	1		
POTR	0.005	0.325	0.612	1	
TSCA	0.057	0.694	0.381	0.181	1

Table 2: Pairwise comparison probabilities (Fisher's LSD Test) for Soil Bulk Density. Balsam Fir=ABBA, ACSA=Sugar Maple, PIRE=Red Pine, POTR=Trembling Aspen and TSCA=Hemlock.

	ABBA	ACSA	PIRE	POTR	TSCA
ABBA	1				
ACSA	0.165	1			
PIRE	0.036	0.003	1		
POTR	0.025	0.002	0.842	1	
TSCA	0.842	0.224	0.025	0.018	1

Table 3: Pairwise comparison probabilities (Fisher's LSD Test) for Humus Depth. Balsam Fir=ABBA, ACSA=Sugar Maple, PIRE=Red Pine, POTR=Trembling Aspen and TSCA=Hemlock.

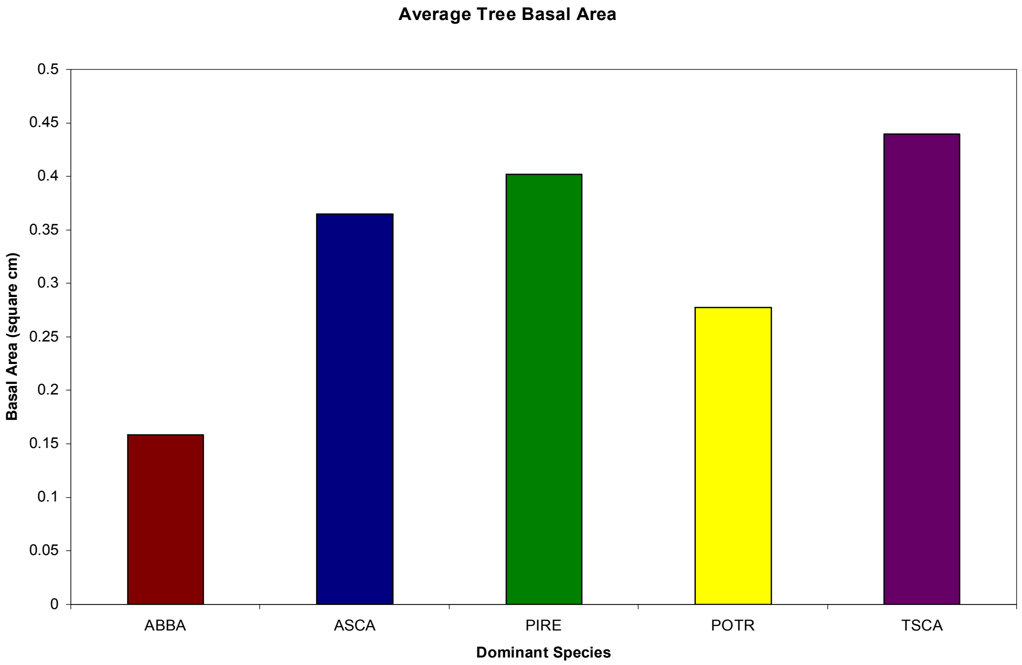


Fig. 5: The tree basal area, averaged for each species over the three sites.

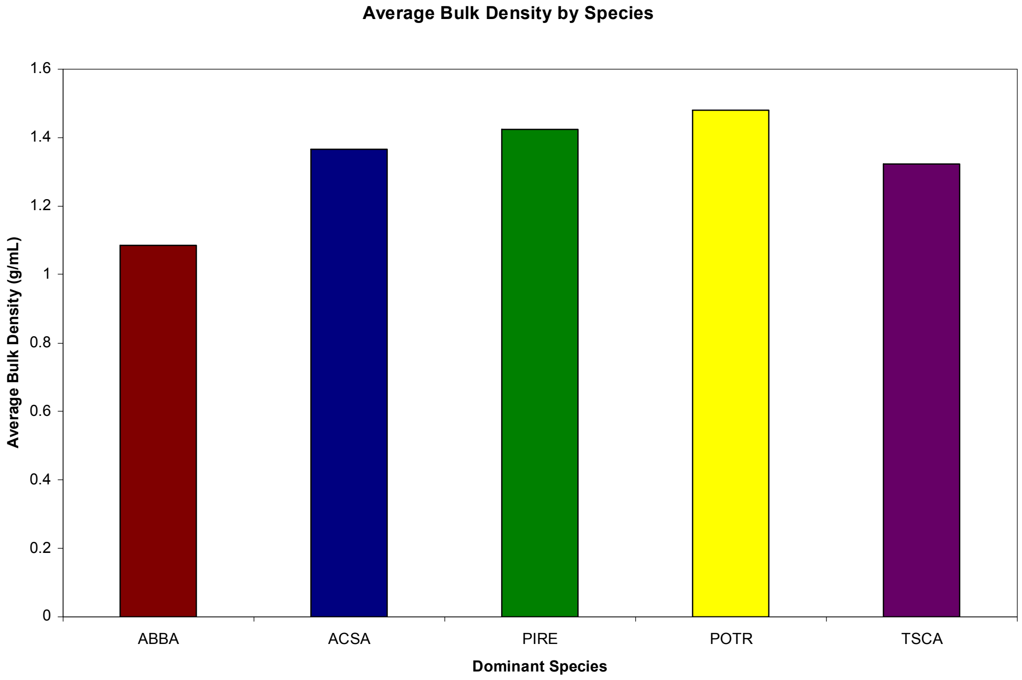


Fig. 6: The soil bulk density, averaged for each species over the three sites.

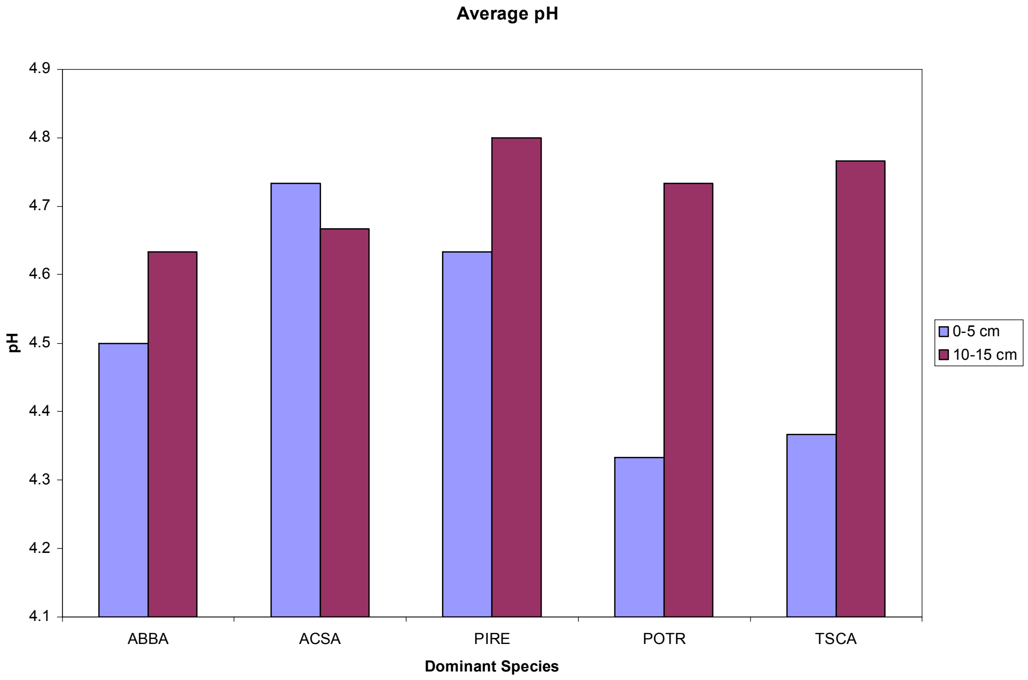


Fig. 7: The pH measurement, averaged for each species at each of the depths measured.

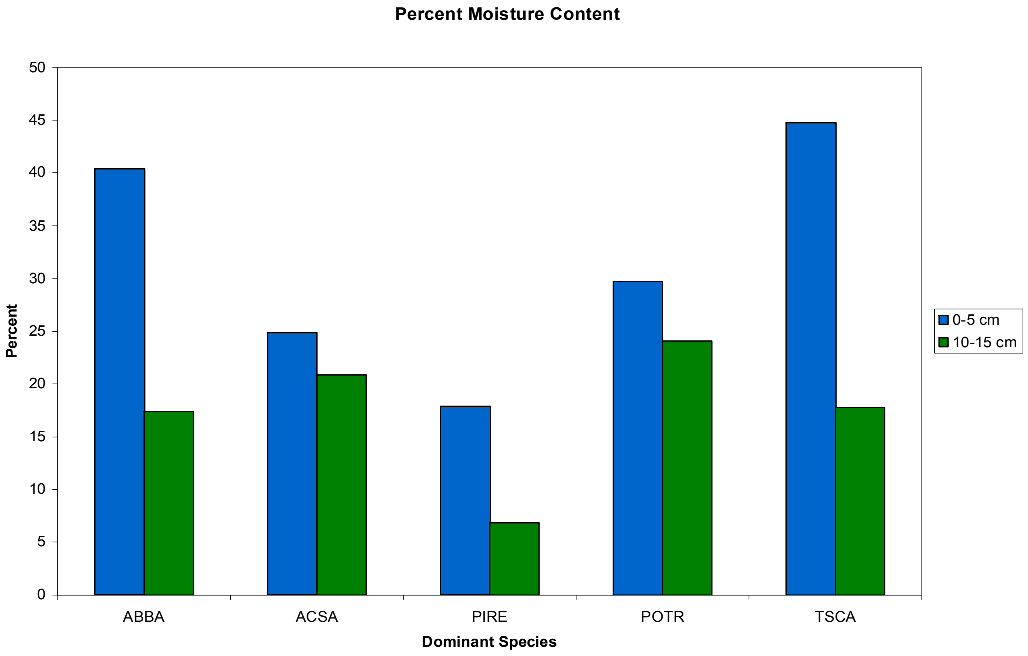


Fig. 8: The moisture content percentages averaged for each species at each of the depths measured.

	ABBA	ACSA	PIRE	POTR	TSCA
ABBA	1				
ACSA	0.361	1			
PIRE	0.004	0.031	1		
POTR	0.856	0.461	0.006	1	
TSCA	0.719	0.207	0.001	0.589	1

Table 4: Pairwise comparison probabilities (Fisher's LSD Test) for Soil Moisture Content. Balsam Fir=ABBA, ACSA=Sugar Maple, PIRE=Red Pine, POTR=Trembling Aspen and TSCA=Hemlock.