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ES 102

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# SUCCESSION IN THE COASTAL FORESTS OF WASHINGTON:
## LOGGING, SOILS AND VEGETATION

**Introduction**

As a child, I was keenly aware of the land. I grew up at the edge of the largest wilderness forest in the lower 48 states, far from other children, so I spent much time in the woods and fields. They were my home; their rhythms were my rhythms. At this time I was aware that all forests were not the same. Some were comprised of evergreen trees, some of leafy trees. Within the evergreen forests, there were areas with big trees and lots of dead wood, and areas with big stumps, but no big trees. Even as a child, I was curious about the reasons for these differences.

Over several days in March of 1994, I had the chance to return to the forests of my youth, and look at these differences through the lens of the science I have been learning at Williams. The forest, I saw, was divided into three distinct successionary regimes. At the western edge, climax Douglas Fir forest covered the land (referred to as zone 3). Further to the east I could distinguish a belt of mature second growth forest (zone 2), similar to the old growth, but lacking the huge trees and showing evidence of logging (notched stumps, iron cable, etc.). Finally, at the eastern edge of the land, I found a still younger forest of Bigleaf Maple, Alder, and Western Red Cedar(zone 1).

I set about quantifying some of the apparent differences between the three forest types. I dug soil pits, and gathered samples from each layer of soil, and gathered more samples between zones. I conducted surveys of the vegetation. My goal was to understand how the history of the forests relate to the different biotic and abiotic variables I analyzed. For each variable I ask has this been effected by land use history in a way I can measure? If so, how and why?

In order to arrive at meaningful answers to these questions, some understanding of the larger context in which these forests exist is necessary.

**Geological and Geographical Context**

I live in Whatcom county, in the extreme northwest corner of Washington state, about 18 miles east of Puget sound, and about 20 miles south of the Canadian border. Most of our weather comes from the Fraiser River Valley, 50 miles to the North. The average rainfall for the area is between 50 and 60 inches annually, with accumulations of up to 85 inches not uncommon. Most of the precipitation (70%) falls between October and March. During the summer months, monthly rainfall seldom exceeds three inches. Temperatures are less varied: average summer highs tend to be in the low 80's (°F), while winter lows seldom drop below the mid 20s.

Our land is in the valley formed by the south fork of the Nooksac river, on the northwest flank of the Van Zant Dike, one of the foothills of the North Cascades. The sites sampled are between 250 and 400 feet above the floodplain of the valley floor, and about a mile distant from the river itself. The bedrock of the northern part of the Van Zant dike is folded and tilted sandstone. To the south, it shifts to sheared and faulted phyllite. During the last glacial period, the region was covered by ice over 4,000 feet thick. This ice rounded and smoothed the topography, and left behind undifferentiated deposits of glacial till and gravel. With the departure of the glaciers, massive erosion further reduced the hills, creating alluvial deposits on top of the glacial materials.

This means that our land is on top of two water tables: one unconfined, in the alluvial deposits of the last 15,000 years, and another, confined aquifer below the impervious glacial till. Consequently, our soils are very well drained, but not saturated with runoff from higher up the hillside, where the confined aquifer is recharged.

**Land Use Context**

Up until the mid 1800's, the south fork valley was the exclusive domain of the Nooksac Indian Tribe. In 1855, however, the Nooksac signed a treaty with the US government ceding all their traditional lands in exchange for cash and schooling. By the last years of the 19th century, German, Dutch and Scandinavian settlers were streaming into the area. The early economy depended on farming, but, as settlers began to exploit the rich timber, this rapidly shifted to a timber based economy.

Most of the valley and surrounding hills were logged in the first 20 years of the 20th century, using a steam powered railroad. In 1915, a major fire burned much of the remaining timber. Little land escaped the scourges of fire and saw; the western extreme of our property is among the surviving ancient forest.

In zones 1 and 2, evidence of this history of logging abounds. In places the forest is littered with old cables, railroad spikes, and crosscut saw blades. Perhaps the clearest sign of a logged area are the stumps, notched from the springboard the loggers would stand on while cutting.

Land was logged in two ways at the beginning of the century. In places where access to transportation was easy and slopes were gently, loggers cut the land clear, removing all but the youngest trees. If rivers or railroads were distant, or if the timber was of poor quality, loggers "high graded", or selectively cut and removed only the biggest, best trees. I hypothesize that zone 1 was clear-cut, while zone 2 only had selected trees removed. This explains why the two zones are so different despite their proximity. It is logical that the loggers would choose to stop cutting all the trees as they progressed farther from the railroad that ran down the valley.

**Materials and Methods**

I examined the soils and vegetation of each zone, and gathered soil samples along a transect that cut across all three zones.

*soilpits*:

In each of the zones, I dug a soil pit. These pits revealed the structure of the soil, and allowed me to gather samples from each soil horizon.

*vegetation*:

I sampled the basal area of tree species at each soil pit using a basal area prism with a factor of 10. I identified and counted understory species in 100 $m^2$ plots near each soil pit.

*soil transect*:

In an effort to better understand how soils change throughout the three zones, I gathered samples from the O horizon along a transect that ran through all three zones. I gathered samples form deep within each zone, and from the transitional areas between zones.

*lab analysis*:

I brought all my soil samples back to Williamstown, where I analyzed them for a number of variables. In all samples, I looked at the pH and, by heating the soil and recording the resulting change in weight, the moisture and organic content. For the A and B horizons, I used a soil hydrometer to measure particle size (silt vs. clay vs. sand). In all but the C horizon, I analyzed for cations $K^+$, $Mg^{+2}$, and $Ca^{+2}$ using a ion chromatographer.

**Error**

Because of a misunderstanding on my part, I did not collect O layer samples from my soilpits. I did gather O layer samples from a transect that passed near each soil pit. To make my layer analyses complete, I inserted data from the transect samples into the missing O-layer section. This increases all my uncertainties slightly.

The pH, %L-O-I, and %moisture data were all came from very simple tests, performed with accurate instruments. Consequently the uncertainty on them is low, no more than 5%. The soil texture measurements were much less accurate. The soil hydrometer was fairly difficult to read, making the uncertainty a relatively high 10%. The cation analyses was complicated and had many opportunities for small errors, giving it an uncertainty of about 10% as well.

The vegetation data were all very simple to gather. They are accurate to within 5%. The major problem with the biological data is its simplicity: I didn't have the time or the knowledge to look carefully at mosses, fungi, and animals. In addition, I did my sampling in the early spring, before many of the understory plants were above ground. Thus, my vegetation data only reflects the trees and perennial understory species.

**Raw Data/Observations**

Here I describe the forests in more detail, and present some of the data. Tables 1-4 quantify much of these data.

The deciduous forests in zone 1 were, by my simple analyses, the most biologically diverse; It was home to 76% of all the species I found, 40% of which occurred exclusively in this zone. Alder, Bigleaf Maple and, in a few places, Western Red Cedar, dominated the canopy. The understory was dense with Salmon Berry and Chokeberry bushes. Later in the year Stinging Nettles will fill in all the gaps between bushes. Mosses and lichens were also most evident in this zone. All fallen logs, all maple trees and the bottom three feet of other trees were cloaked in moss. The upper parts of the alders were covered with lichen. I was not able to identify the lichens and mosses, but there appeared to be no more than 5 species of lichens and 3 species of mosses.

The vegetation tended to be in clumps and groves: here a patch of alder, there a patch of vine maple. This may be a result of the seeding patterns after the land was logged, or it may be a function of soils. Throughout the forest, however, there were lots of young Western Red Cedars and Douglas Firs, a sign that the forest is changing.

Structurally, zone 1 was the least diverse. Nearly all of the trees were under three feet in diameter at breast height. The few large trees were fast growing, early succession maples and alders. With the exception of rotting stumps and a few random branches, there was little dead wood on the forest floor. Nowhere did I see young plants colonizing fallen logs. As well as being free from wood, the forest floor tended to be relatively flat. There were few pits and mounds associated with falling trees. It was difficult to judge the nature of the canopy without the leaves out, but it appeared as if in the growing season the deciduous trees would block most of the light. In other words, there were few large gaps in the canopy.

The soils of zone 1 were relatively thin and sandy (see Table 1, Figures (x) and (x)). In the A horizon, all the clay had been washed away, of the three zones, they were composed of the highest percentage of sand. In contrast with the other zones, the O layer in zone 1 contained no charcoal. The soils of zone 1 tended to be more acidic, especially in the O and C horizons. The organic content (%L-O-I) and %moisture in zone one were indistinguishable from that of other zones. The same tended to be true with cations.

Signs of human use abounded in this former clear-cut. I observed dozens of stumps with clear springboard notches. About 500 meters to the west of the sample sight, still well within zone 1 type forests, I found an old piece of logging cable.

About 300 feet to the north of my sample site in zone 1, Bigleaf Maples and Alders began to give way to the Western Red Cedars and Douglas Firs of zone 2. Within 500 feet, the forest appeared completely different. A closed evergreen canopy replaced the openness of below. Mid-sized Red Cedars and Douglas Firs dwarfed an occasional Bigleaf Maple. The understory was open and covered with scattered sword ferns and Oregon grape. Only about half of the species I found occurred in zone 2. Mosses and lichens, apparently of the same species as I observed in zone 1, grew sporadically.

Like zone one, zone two was scattered with notched stumps. On Average, however, the stumps were larger and more infrequent. This supports my hypothesis that zone 2 was the sight of selective cutting.

The forest floor in zone 2 was scattered with small dead trees and occasional large trunks. In places I saw young trees growing out of these fallen trunks. Beyond these, young trees were fairly infrequent. The forest floor was fairly uneven, with pits and mounds resulting from decomposed, fallen trees fairly common. The dominant trees tended to be roughly the same diameter (20-35 inches at breast height). They also tended to be roughly the same height. Consequently they formed a fairly even, unbroken canopy. In several places snags rose above the canopy.

Zone 2's soil texture is best described as the average of zones 1 and 3. They were sandier than zone 3, but contained more silt and clay than zone 1. They also contained bits of charcoal, presumably from the fire of 1915. This was not true for pH: in the O layer, the pH's of zones 2 and 3 are nearly identical, suggesting a correlation with vegetation. I found a slightly higher, but statistically irrelevant, level of cations in zone 2. Once again, %L-O-I and %moisture seem unrelated to forest age.

Another 500 feet uphill, in zone 3, the cut stumps disappeared, huge trees began to appear, and the structure of the canopy and forest floor changed drastically. Douglas Fir emerged as the dominant species, challenged only by an occasional Western Red Cedar. Some trees were huge, up to about 6 feet in diameter, while others where no more than saplings. The uneven, layered canopy reflected this diverse of age. Many of the older trees had large cavities in their trunks. Snags abounded, and many were pocked with woodpecker holes. Fallen logs in many different stages of decomposition littered the forest floor.

Nearly all these logs were home to small trees. The forest floor was very broken up: in places huge pits and mounds marked where huge trees had fallen. As in zone 2, my method of counting species suggested relatively low diversity of trees and understory shrubs. I observed, but did not identify, at least 5 kinds of fungus not found in zones 1 and 2. The mosses and lichens differed little from zone 2.

The soils of zone three had the most silt and clay of the three sites. As before, the cation, %L-O-I and % moisture measurements do not differ substantially from the average. The pH was indistinguishable from zone 2, but significantly higher than in zone 1.

**Conclusions: What the Data Suggests About Succession**

The data suggests that forest succession effects pH, soil texture, horizon depth, and vegetation. The other factors I measured, %L-O-I, %moisture, and cations, appear to vary independently of forest age. This may indeed be true, or it may be a reflection of faults in sampling or analysis techniques.

The relationship between soil texture and forest age was both clear and meaningful. Figures 1 and 2 show that %sand decreases with age while %sand and silt increase. In other words, ancient forests tend to have more silt and clay than second growth. This is almost definitely the result of erosion: after the soils are made vulnerable by logging, the smaller, lighter silt and clay particles are carried away, leaving a higher percentage of sand.

The implications of this are twofold. First, because clay particles have negatively charged surfaces that readily bind to cations, erosion may deplete the quantity of cations available to plants. This loss is particularly important because these clay particles will be very slow in re-accumulating. This hypothesis is weakened by the fact that cation analysis I performed reflects little or no variation in cation concentrations between zones. The only explanation for this apparent discrepancy that I can think of is that the cation measurements are for some reason inaccurate. Second, the particles that are washed down slope must come to rest somewhere. My guess is that they ended up in the river, where they cause sedimentation problems, which in turn can contribute to flooding.

The differences between horizon depths in different layers, illustrated in Figure 3, confirm that logging causes erosion. As forest age decreases, the thickness of the O and A horizons drops considerably. This underscores the fact that logging causes major structural change in the abiotic foundation for forests.

Figures 6-7 show that pH varies significantly in the O and C horizons. The variation in the O horizon (Figure 6) is quite simple: zones 2 and 3 are significantly more alkaline than zone 1. I hypothesize that this is due to changes in vegetation. Zones 2 and 3 are covered with conifers, while zone 1 is primarily deciduous. The correlation between vegetation and pH suggests that falling leaves from the trees in zone 1 are contributing $H^+$ ions responsible for the acidity of the soil.

The trend in the C horizon (figure 7) shows is slightly more complex, but based on the same idea. $H^+$ ions come from the leaves, and leach through the soil. They tend to accumulate in the C layer. Zone 1 has a high pH because it never experienced leaf fall. Zone 2 has a medium pH because it went through a period of high leaf fall in the years following logging, and Zone 1's low pH is due to continuing leaf fall.

Both trees and the understory vary with forest age. As forest age increases, basal area increases (Table 4), and diversity throughout the forest appears to decrease (Tables 3 and 4). This first trend is basic: old forests have bigger trees. The second trend is misleading. I hypothesize that this appears to be true because my sampling techniques measured only a fraction of the total species present.

**Conclusion**

I had always been told that logging changes the land. This project reveals how deep and permanent the changes are: logging different pH environment in the soils, different soil textures, different horizon structure. This is true even if the forest is selectively cut, as evidenced by the changes that took place in zone 2.

As well as teaching me about the impacts of logging and the ecology of succession, doing an independent project like this helped my understanding of what it means to do science.

Soil pit descriptions? sketches/photos for all. Layer thicknesses? Layers in pits ... would make data more complete.

The O-A layer and particle size analysis are convincing! Nice!

| | sample | pH | %moisture | %L-O-I | %sand | %clay | %silt | Ca++ | Mg++ | K+ | sample |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | IO | 6.13 | 20 | 5.4 | | | | 4125 | 300 | 125 | IO |
| 1 | IIO | 5.99 | 13 | 4.4 | | | | 7125 | 575 | 175 | IIO |
| 2 | IIIO | 4.71 | 12 | 4.2 | | | | 3325 | 450 | 100 | IIIO |
| 3 | IA | 6.14 | 11 | 3.2 | 84 | 0 | 16 | 5675 | 425 | 125 | IA |
| 4 | IIA | 6.08 | 12 | 4.6 | 79 | 4 | 17 | 5900 | 400 | 175 | IIA |
| 5 | IIIA | 6.12 | 8 | 2.3 | 53 | 10 | 37 | 4325 | 200 | 125 | IIIA |
| 6 | IB | 6.36 | 5.6 | 1.6 | 76 | 4 | 20 | 3700 | 200 | 75 | IB |
| 7 | IIB | 6.28 | 5.9 | 1.9 | 72 | 6 | 22 | 3050 | 175 | 100 | IIB |
| 8 | IIIB | 6.30 | 5.8 | 3.2 | 59 | 9 | 32 | 2775 | 225 | 100 | IIIB |
| 9 | IC | 6.34 | 5.1 | 0.38 | | | | 3300 | 150 | 75 | IC |
| 10 | IIC | 6.47 | 9.6 | 2.4 | | | | 4125 | 200 | 825 | IIC |
| 11 | IIIC | 6.86 | 5.7 | 1.5 | | | | 2800 | 450 | 150 | IIIC |

TABLE I: SOIL DATA BY LAYER

| | Sample | pH | % moisture | % L-O-I | %sand | %clay | %silt | Ca++ | Mg++ | K+ | sample |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | zone 3 | 6.13 | 20 | 5.4 | | | | 3325 | 450 | 100 | A |
| 1 | zone 2/3 | 5.68 | 16 | 5.3 | | | | 3175 | 325 | 150 | B |
| 2 | zone 2 | 5.99 | 13 | 4.4 | | | | 7125 | 575 | 175 | C |
| 3 | zone 2/1 | 4.55 | 21 | 7.4 | | | | 10425 | 850 | 175 | D |
| 4 | zone 1 | 4.71 | 12 | 4.2 | | | | 4125 | 300 | 125 | E |
| 5 | IA | 6.14 | 11 | 3.2 | 84 | 0 | 16 | 5675 | 425 | 125 | IA |
| 6 | IB | 6.36 | 5.6 | 1.6 | 76 | 4 | 20 | 3700 | 200 | 75 | IB |
| 7 | IC | 6.34 | 5.1 | 0.38 | | | | 3300 | 150 | 75 | IC |
| 8 | IIA | 6.08 | 12 | 4.6 | 79 | 4 | 17 | 5900 | 400 | 175 | IIA |
| 9 | IIB | 6.28 | 5.9 | 1.9 | 72 | 6 | 22 | 3050 | 175 | 100 | IIB |
| 10 | IIC | 6.47 | 9.6 | 2.4 | | | | 4125 | 200 | 825 | IIC |
| 11 | IIIA | 6.12 | 8 | 2.3 | 53 | 10 | 37 | 4325 | 200 | 125 | IIIA |
| 12 | IIIB | 6.30 | 5.8 | 3.2 | 59 | 9 | 32 | 2775 | 225 | 100 | IIIB |
| 13 | IIIC | 6.86 | 5.7 | 1.5 | | | | 2800 | 450 | 150 | IIIC |
| 14 | | | | | | | | | | | |
| 15 | | | | | | | | | | | |
| 16 | CHARCOAL | 6.31 | 8.4 | 2.2 | | | | | | | |
| 17 | ORGANIC MATTER:IC | 6.03 | 13 | 4.1 | | | | | | | |

TABLE II: SOIL DATA

| | species | scientific name | zone 3 (oldgrowth) | zone 2 (second growth) | zone 1 (decidous) |
|---|---|---|---|---|---|
| 0 | vine maple | Acer circinatum | 0 | 0 | 5 |
| 1 | elderberry | Sambucus callicarpa | 0 | 0 | 3 |
| 2 | sword fern | Polistichum munitum | 30 | 6 | 25 |
| 3 | trillium | Trillium ovatum | 0 | 0 | 1 |
| 4 | oregon grape | Berberis nervosa | 60 | 14 | 0 |
| 5 | salmon berry | Rubus spectabilis | 0 | 0 | 3 |
| 6 | chokeberry | Prunus virginiana | 0 | 0 | 23 |
| 7 | fallen logs >3' diam | | 12 | 4 | 5 |
| 8 | trees over 3' diamet | | 12 | 7 | 4 |

TABLE 3: UNDERSTORY

what do numbers refer to?
number sampled per plot?

| | species | scientific name | zone 3 basal area (sq.ft/acre) | Zone 2 basal area (sq.ft/acre) | zone 1 basal area (sq.ft/acre) |
|---|---|---|---|---|---|
| 0 | alder | Alnus rubra | | | 35 |
| 1 | western red cedar | Thuja plicata | 30 | 45 | 25 |
| 2 | vine maple | Acer circinatum | | | 10 |
| 3 | bigleaf maple | Acer macrophyllum | | 30 | 90 |
| 4 | douglas fir | Pseudotsuga menziesi | 190 | 110 | |
| 5 | western hemlock | Tsuga hetrophylla | | 10 | |
| 6 | total (all species) | | 220 | 195 | 150 |

TABLE 4: BASAL AREA

%sand

**Fig. 1: young forests have sandier soil**

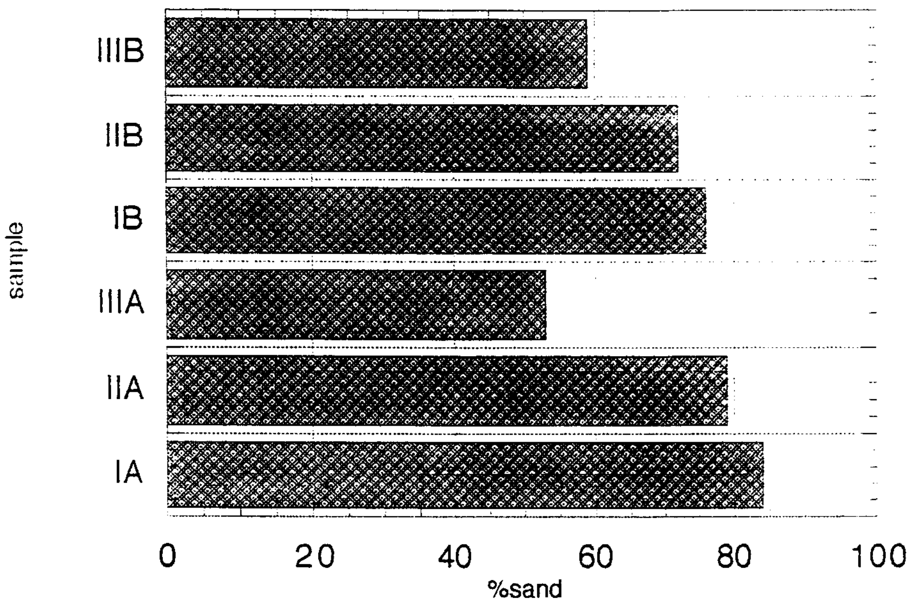



**Fig. 2: old forests have more clay and silt (note IA has no clay)**

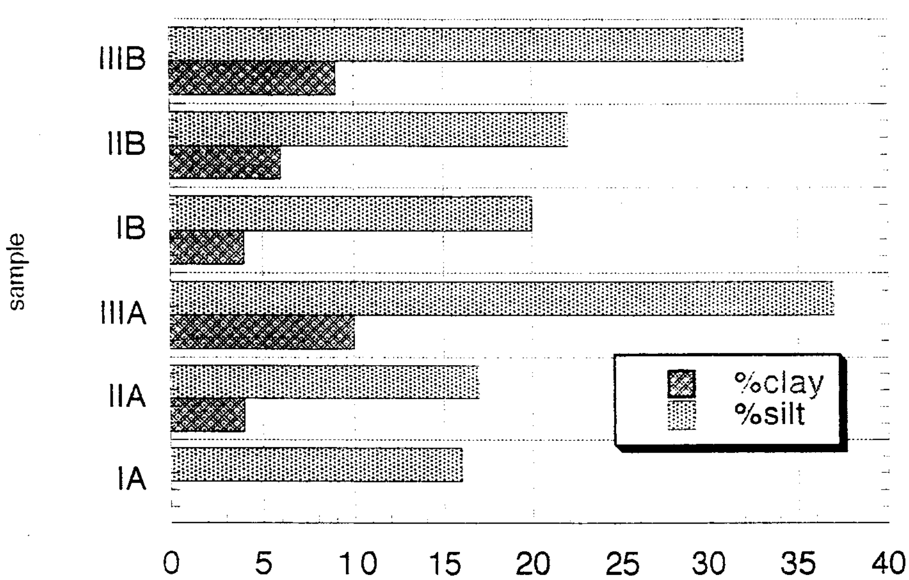


**Fig. 3: Thickness of O and A increase with age of forest**

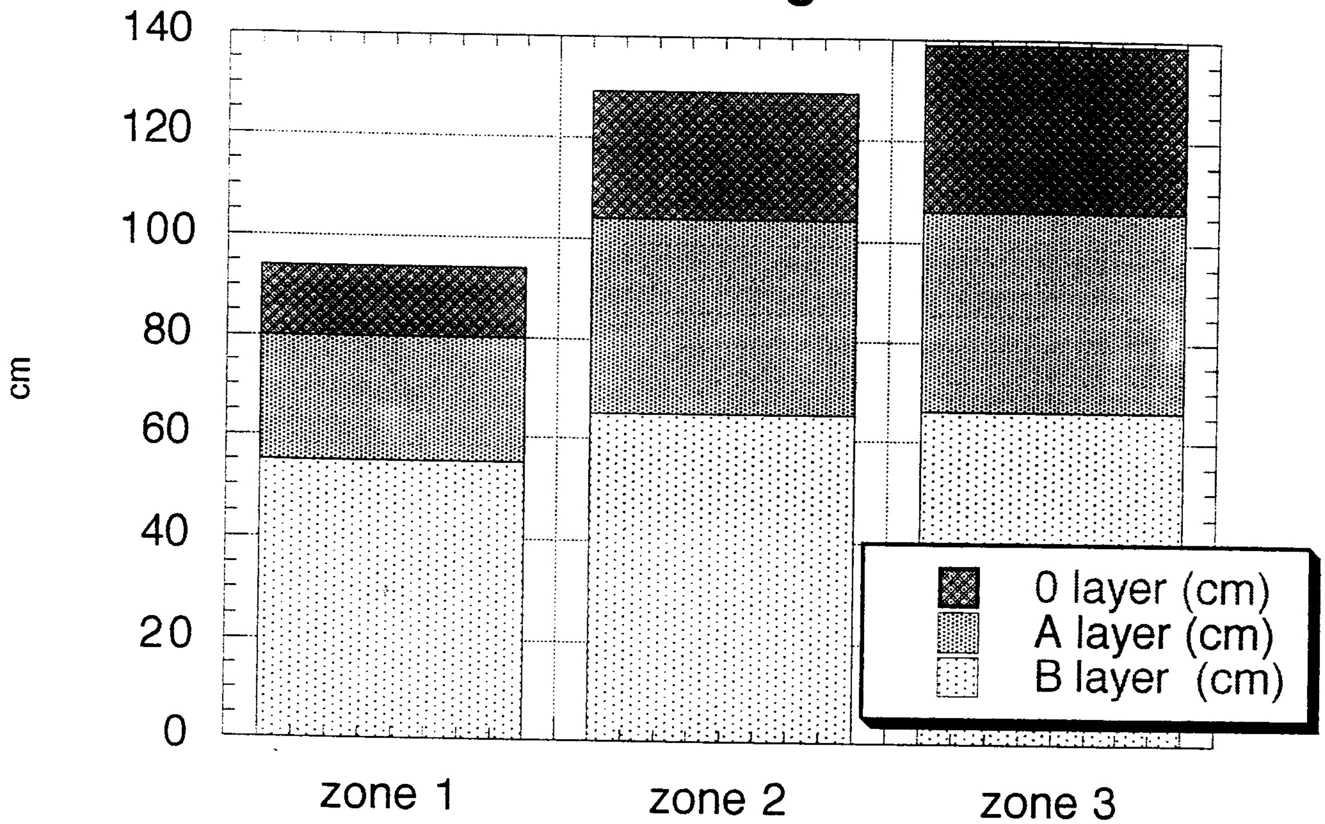


**Fig. 4: pH appears to increase with age**

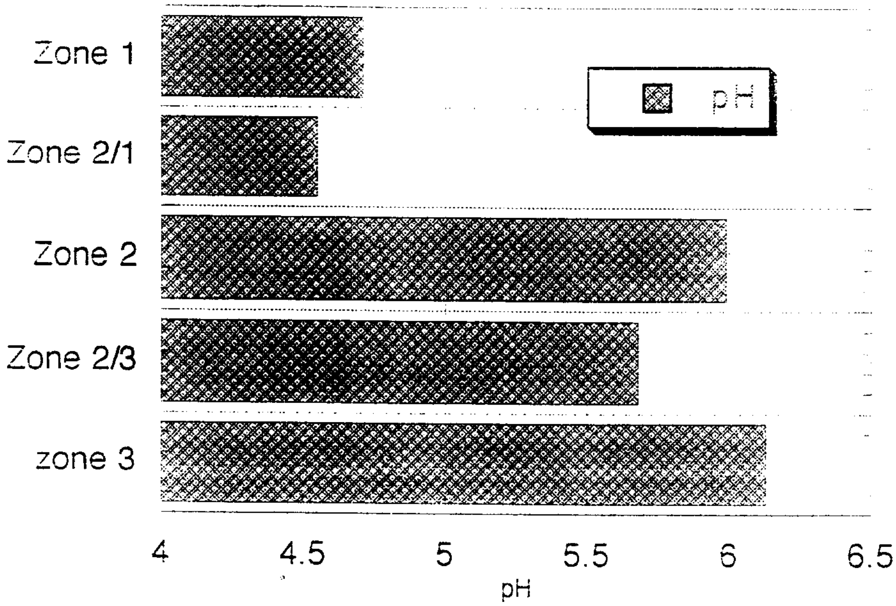
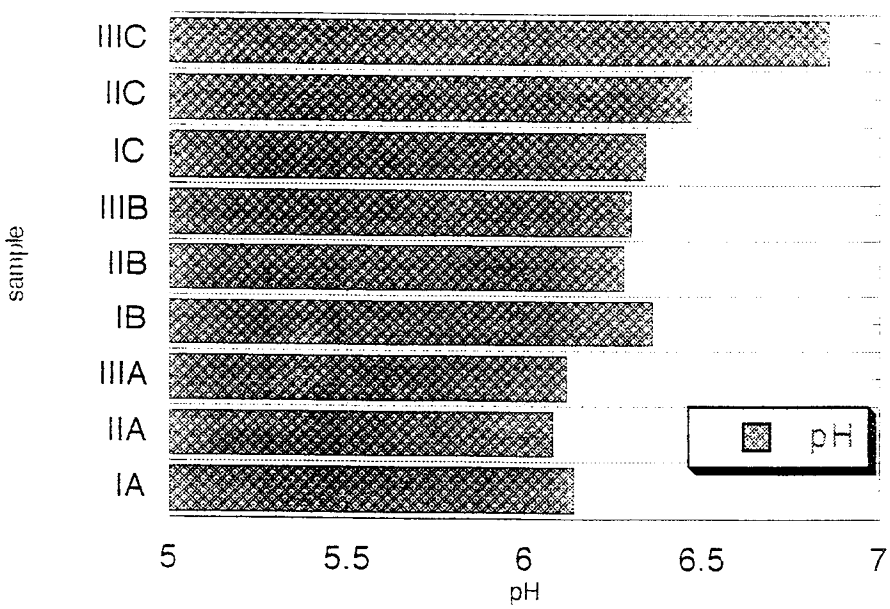



**Fig. 5 pH varies with age in the C horizon**



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This field guide helped me identify trees and shrubs.

Norse, Eliot, editor, Ancient Forests of the Pacific Northwest, 1990, Island Press, Washington, DC.

Provided me with background information on the ecology of succession and the differences between ancient and second growth forests.

Whatcom County Planning Department, South Fork Valley Subarea Background Document, 1990, Bellingham, WA

Background information on land use and geology of the area