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Forest Floor Dynamics Across a Chronosequence in the Coastal Western Hemlock Zone

Introduction

The forest floor represents the uppermost organic and organic-enriched mineral soil horizons. They have been formed by the deposition of organic material and the subsequent biologically-mediated decomposition. The forest floor influences rooting-zone temperature, aeration, moisture, and nutrient conditions, and hence, forest productivity. Considering the importance of the forest floor, and the fact that it is exposed to disturbance (being the surface layer), we need to assess the potential impacts our logging practices may have.

Clearcutting, one of the contentious silvicultural practices used in British Columbia, is imputed to most adversely affect ecosystems and sustainability. We assessed the long-term impact of clearcutting on the forest floor by documenting changes in the thickness, chemical and biotic properties of the humus form across a chronosequence of forest stands. The study was located in the largest and most representative portion of the coastal rainforest- the Very Wet Maritime Coastal Western Hemlock (CWHvm) subzone.

The chronosequence

In order to study long-term changes expediently, we used a chronosequence approach, *i.e.*, we investigated three stages of stand development (or succession) compared to a benchmark old-growth stage. The developmental stages examined were:

(1) **old-growth**, represented by an open-canopy, multi-storied, uneven aged (trees from 100 to 890 years) mixture of western redcedar, western hemlock, and Pacific silver fir, with scattered Douglas-fir, and well developed understory vegetation;

(2) **stand initiation**, represented by a 7 year-old cutover with planted Douglas-fir, naturally regenerated western hemlock and western redcedar and early seral vegetation;

(3) **stem exclusion,** represented by a naturally established (30-40 years after cutting), unmanaged, dense, closed-canopy, even-aged mixture of western hemlock with scattered Pacific silver fir and Douglas-fir, and poorly developed understory vegetation;

(4) **understory reinitiation,** represented by a naturally established (50-80 years after clearcutting), unmanaged, semi-open canopy, even-aged mixture of western hemlock, Pacific silver fir and Douglas-fir, with moderately well-developed understory vegetation.

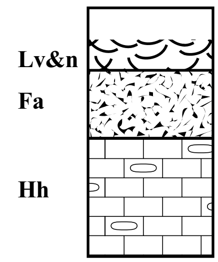
Twelve stands, three for each developmental stage, were located on zonal sites identified according to the biogeoclimatic ecosystem classification system as having a fresh soil moisture regime (no water deficit or excess) and medium soil nutrient regime.

Humus form profiles

(1) Old-growth

This profile represents a Mormoder humus form.

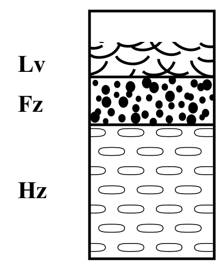
- **Lv&n** horizon of new (n) and old (v) litter
- **Fa** (amphimorphic) horizon, moderate non-compact matted structure with fungal mycelia and fine roots common
- thick **Hh** (humic) horizon, with a blocky to granular structure and scattered clusters of decaying wood



(2) Stand initiation

This profile is a typical Leptomoder and although Mormoders are present too, this is the predominant humus form.

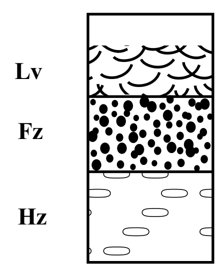
- **Lv** horizon of mostly old litter
- thin **Fz** (zoogenous) horizon of partly decomposed plant residue which are weakly aggregated and have loose or friable consistency
- thick **Hz** horizon has a granular structure due to the faunal droppings which constitute most of the fabric



(3) Stem exclusion

This profile represents a Leptomoder humus form.

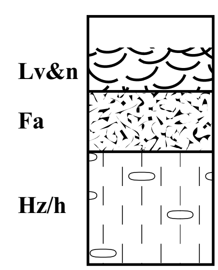
- **Lv** horizon
- **Fz** as in stand initiation stage
- **Hz** horizon is thinner than in stand initation stage and faunal droppings are less abundant

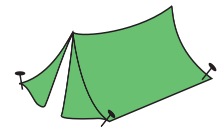


(4) Understory reinitiation

This profile is a Mormoder. Leptomoders are still present in this successional stage, accounting for 30% of the humus forms.

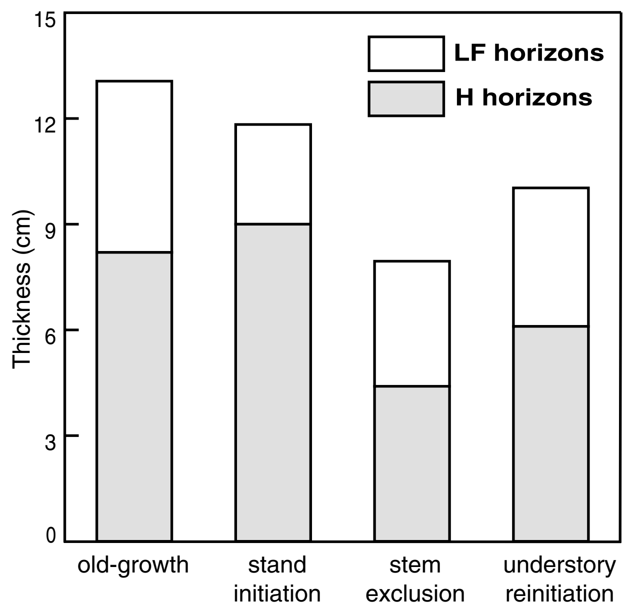
- **Lv&n** horizon
- **Fa** horizon
- **Hh/z** (humic/zoogenous) horizon, with scattered faunal droppings and predominance of fine substances





How has clearcutting affected the forest floor materials?

The presence of a relatively thick forest floor is needed to protect the mineral soil from erosion (erosion risk is high in the coastal rain forest) and to maintain a nutrient pool for the biotic community. In this study the forest floor was preserved during harvesting operations, so its thickness in the stand initiation stage remained about the same as it was in the old-growth stage. The forest floor thickness sharply decreased between the stand initiation and stem exclusion stages, where it reached a minimum, and increased from the stem exclusion to the understory reinitiation stage. This decrease and subsequent increase parallels the changes in litter inputs and decomposition rates in the forest floor. In the stand initiation and stem exclusion stages, where forest growth is vigorous, the litter inputs are low and decomposition is high, while the reverse is true in the old-growth stage.



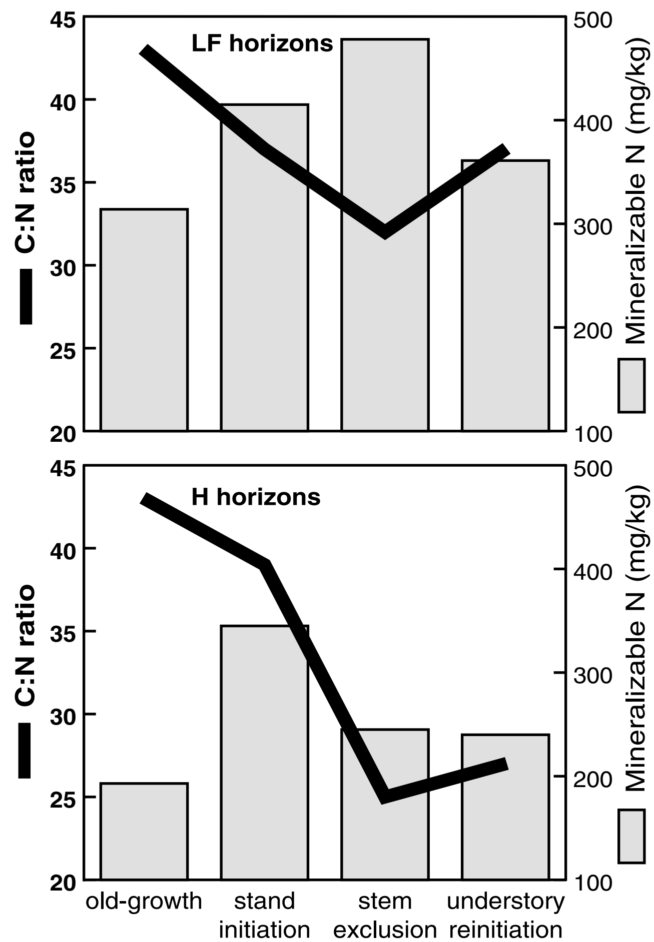
Changes in thickness of the combined L and F and H horizons across the four developmental stages.

How has clearcutting affected the forest floor nutrient pool?

We used two indices - carbon:nitrogen (C:N) ratio and mineralizable N (minN) - to infer the amount of easily available soil nutrients in the forest floor. In general, higher C:N ratios are associated with lower organic matter decomposition, and higher amounts of N mineralization are associated with higher soil nutrient availability.

Variations in the C:N ratio and minN from the old-growth stage across the chronosequence gives an indication of the decomposition rate and nutrient availability. C:N was highest and minN lowest in the old-growth stage. Immediately after clearcutting, C:N declined and minN increased. This trend continued between the stand initiation and the stem exclusion stages for C:N and minN in the LF horizons. The increased mineralization is a result of the exposure of the original forest floor material, added logging residue and high quality litter from new vegetation to the open area climate (increased temperature and moisture) created by clearcutting. However, this increase was not so rapid as to dramatically reduce the forest floor before canopy closure, a period of high demand for soil nutrients, had occurred.

From the stem exclusion stage to the understory reinitiation stage, C:N increases somewhat and minN decreases. This trend may reflect the changes in microclimate through canopy closure, and the accumulation of recalcitrant materials, such as the large inputs of lignin from decaying wood.

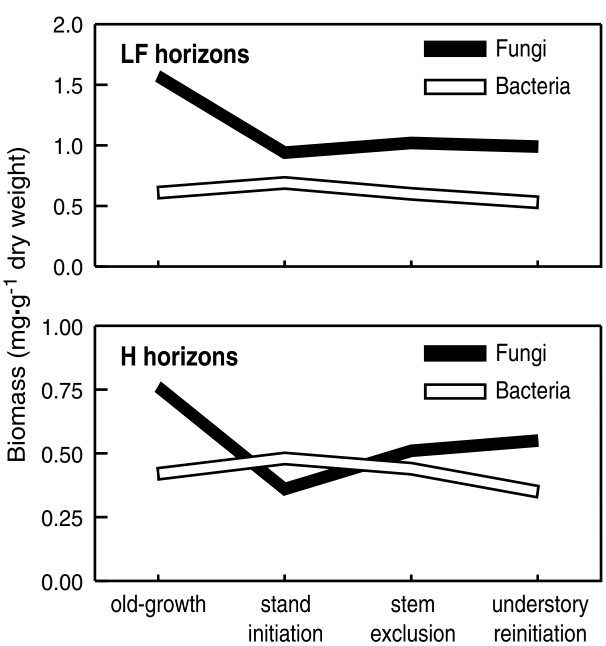


Changes in C:N ratio and mineralizable N in the LF and H horizons across the four developmental stages.

Has clearcutting affected the hidden life: soil fauna, fungi and bacteria?

Decomposition of the forest floor materials results from the complex interaction of many different soil organisms, known collectively as the food web. Any substantial variation in the number of organisms or composition of the soil biotic community may lead to a disruption (undesirable change) in decomposition and nutrient release.

Bacteria and fungi form the base of the soil food web. In this study, the bacterial biomass showed very little change through the entire chronosequence. On the other hand, the fungal biomass showed a large decrease after clearcutting, reaching a minimum at the stand initiation stage, and then showing signs of increase in subsequent stages. The depression of the fungal community after clearcutting may be the result of a decrease in live tree roots (therefore, a decrease in the mycorrhizal community) and the decreased acidity of the LF and H horizons. This decrease in acidity, from pH 3.6 in the old growth to pH 4.4 in the stand initiation stage may be due to the mineralization of the Ca-rich litter of western redcedar. Forest floor fungi are less tolerant of pH above 4.5.



Changes in fungal and bacterial biomass in the F and H horizons across the four developmental stages.

Groups of soil fauna represent the grazers (different groups feed on the various saprophytic and mycorrhizal fungi, and living and dead plant material) and predators in the food web. In this study, 31 groups of soil fauna were identified to the taxonomic level of Family and above. Unfortunately, only broad taxonomic groups can be identified, due to the difficulty of identifying soil fauna to the species level, the level at which food and habitat preferences are displayed. Furthermore, there is a great deal of variation in the samples collected. Nevertheless, some broad trends were evident.

Roundworms, mites, and springtails accounted for 97% of all the fauna. Only the springtails were significantly higher (α=0.05) in the old-growth stage compared to the three stages of the chronosequence. The stand initiation stage had the lowest number of soil faunal groups, and lacked three groups which occurred in the other stand developmental stages. One of these groups, the spiders, was only observed in the understory reinitiation and the old-growth stages. This one group is important as it represents a top predator in the soil food web and when present, can be seen as indicative of an increase in the complexity of the food web.

Numbers of individual (x10^3m^{-2}) roundworms, mites and springtails in the four developmental stages.

	Old-growth	Stand initiation	Stem exclusion	Understory reinitiation
Roundworms (Nematoda)	4235	3250	3347	3842
Mites (Acari)	390	223	227	216
Springtails (Collembola)	137	86	70	54
Other	12	4	4	4
Total	4774	3563	3645	4116

Clearcutting, and the associated changes in microclimate and decomposition rates, induced alterations in the forest floor biotic community. The greatest impact was on the biomass of the fungal community and on the numbers of springtails, both decreasing significantly after cutting. Neither of these two communities showed a recovery to the original old-growth amounts even at the understory reinitiation stage. The bacterial community appeared to be unaffected by clearcutting, although differences in taxonomic classes were not looked at. Besides springtails, other general taxonomic groups in the faunal community appeared to maintain the same levels.

What are the impacts of clearcutting?

After clearcutting, there were inevitable qualitative and quantitative alterations to the forest floor as the result of the change from a modified to an open-area climate. Even if the forest floor materials are preserved during harvesting, the structure and composition of the forest floor community will be altered.

Using the old-growth stand as a benchmark, clearcutting brought clear changes and some of these differences were maintained up to the understory reinitiation stage. In the old-growth forest a non-compact matted Mormoder was the prevailing humus form. In the stand initiation stage, the increased decomposition of the forest floor materials resulted in the development of a friable, Leptomoder humus form, which was maintained through the stem exclusion stage. In the understory reinitiation stage a non-compact Mormoder becomes the dominant humus form. These changes in humus forms were accompanied by increased minN, and decreases in LFH thickness, C:N ratio, fungal biomass, and springtail populations. Although some of these features appeared to be recovering at the understory reinitiation stage (LFH thickness, C:N, minN, spider populations), other features decreased after clearcutting and were maintained at this reduced level (fungal biomass, springtail population).

Whether these changes will negatively affect sustainability or biodiversity is open to further research. Any effect is also dependent upon:

(1) the degree of preservation of the old-growth forest floor after cutting;

(2) whether a variety of microenvironments will be provided in our managed forests, which will result in the development of a diverse pattern of humus forms;

(3) at which stage second-growth and subsequent forests will be harvested again, *i.e.* whether at the understory reinitiation stage or older; and

(4) the size and pattern of clearcutting across the landscape.

Reference

Fons J. and K. Klinka. 1990. Temporal variation of forest floor properties in the Coastal Western Hemlock zone of southern British Columbia. Can. J. For. Res. 28:582-590.

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