

Cindy Prescott

Co-editor, Canadian Journal of Forest Research

Dear Cindy,

Here are the reviewers' comments (in italics) with our responses detailed. Many of the comments were suggestions for improvement in the presentation, which were nearly all very helpful. We also made some significant changes to the content of the paper. We omitted the results from the formerly agricultural sites, as suggested by the reviewers. We also doubled the sample size for the analysis of the horizontal distribution of roots (relating biomass in the pits to the density of the surrounding trees), which was possible because we have now completed another study of roots excavated from soil pits in similar sites. We now have more confidence in our results. A manuscript describing that study has been submitted to the Soil Science Society of America Journal. That paper compares the pit method with soil coring, which is also a topic our reviewers asked about, and we can now reference it in the Discussion.

Detailed descriptions of all our changes follow.

MS 05-247

The vertical and horizontal distribution of roots in northern hardwood stand of varying age. Ruth D. Yanai, Byung Bae Park, Steven P. Hamburg

### **Referee #1**

*This paper reports on the effect of stand age class on root biomass and root biomass horizontal and vertical distribution. The data are definitely valuable to the ecological community and therefore should be published. There are relatively few published data addressing root biomass associated with stand age, and this paper contributes well to what little information there is.*

*It was especially interesting to reopen the topic of horizontal spatial distribution, which showed that the discussion should not be closed yet.*

*The manuscript shows many shortcomings though, and should be thoroughly revised by the authors.*

*What I found to be the main weaknesses, was the inclusion of the mature (former agricultural) stands. There are no hypotheses, very few results and no discussion about these stands. It is not clear why they were included in the study.*

I think the real reason they were included in the study is that they were a lot of work to produce and they are not publishable on their own. We did hesitate to include them, and did not hesitate to remove them in this revision.

*What I did not like (and cannot accept) was that one of the major findings in this manuscript, was the difference in fine root biomass between the two age classes. But this difference is NOT significant ( $p = 0.12$ ) and should therefore be interpreted carefully!*

We are indeed careful in describing this difference (see under detailed comments, below). There is an 88% probability that the difference is associated with stand age, which seems to make it worthy of mention.

*Another thing which was disturbing, was the lack of consistency and correctness in the use of units. Further details are given below.*

*I overall liked the manuscript, but have many detailed remarks, on where it can be improved:*

***TITLE:***

*1/1 Would it be possible to put more emphasis on “varying age”? This is also the emphasis of your paper.*

It's not a very catchy title, but it's descriptive of the paper. We can't justify putting more emphasis on stand age, as our results are not very satisfying (as you noted, the p value was 0.12). We couldn't come up with a better title.

***ABSTRACT:***

*Overall: reflects very well the essentials of methodology and findings.*

*Detailed:*

*2/4 soil depth instead of depth*

Done.

*2/6 When the emphasis of the paper lies on the differences between stand ages, it makes sense to also state the age of the “mature” stands, even in the abstract.*

No longer applicable, as the mature stands have been removed from the paper.

*2/10 ...greater in the old stands... This is not clear: greater than what? (than root biomass in the young stands, in the mature stands...?)*

We say “older” now, consistent with the mention of the 55-70 yr-old stands in line 6. Without the mature stands, there should be no possible confusion.

*2/11 soil depth instead of depth*

Done.

*2/23 Two completely different issues should maybe be put in two different sentences*

Is this line in the Introduction, not the Abstract? The sentence that starts on 2/23 I didn't change, as it relates the timing of canopy and root closure. The sentence that ends the abstract relates a conclusion about sampling strategies to the observation of horizontal pattern in root distribution. I didn't separate those two statements, as the conclusion needs to be limited to that portion of the study; it should not be construed as a conclusion of the whole paper.

***INTRODUCTION:***

*Overall: the introduction is built up in a very clear way: first the emphasis on stand age, then the vertical root distribution, then the horizontal root distribution. Yes, the introduction was limited to the purpose of the paper. I found the paragraph about stand age even a little bit too limited (see 3/8). On some places, I would have been more convinced if more references would have been stated. I was not happy with the last paragraph at all. It was not very clear but more importantly, not complete (see 4/8-15).*

Responses follow the detailed comments, below.

*Detailed:*

*2/22 relatively greater? Or: greater than...? This is not clear.*

Changed to “additional.”

*3/1-2 What is the publication state on this reference at the moment?*

It is forthcoming in CJFR and will be cited as such.

*3/4 Stands implies ‘within 1 site’. Maybe it’s better to use ‘at different sites’*

Done.

*3/6 Do you have a reference about this statement on coarse root biomass? (80-100 y)*

We added Fahey et al. (2004) as a reference for the pattern of bole biomass accumulation. There are no measurements of coarse root biomass as a function of stand age. use “presumably” to indicate that no data are available. The sentence in question reads “In contrast, coarse root biomass presumably increases along with bole biomass (Fahey et al. 2005) for 80 to 100 years in northern hardwoods regenerated by clearcutting.”

*3/8 Why do you study two different stand age classes to investigate the “root closure” problematic? You say later on that the stands were selected from a 13-stand chronosequence. Wouldn’t it have made more sense to use data from 13 stands with different ages, if the goal was to determine the timing of root closure? Why do you select 3 similar young stands and 3 similar older stands when the intention was to describe the development of roots as a function of stand age? And where do the former agricultural stands come into picture?*

The question of root closure makes an appealing introduction to our study, but admittedly, the study was not designed to address this question. We added to the Methods section, where we describe our stands. “To pinpoint the age of root closure, we would have liked to excavate pits in all thirteen stands, but the expense was prohibitive. We elected to use multiple younger and older sites as replicates of two widely separated age classes.”

*3/10-11 I disagree with the statement that excavation is the best way to achieve vertical distribution data. The only reason you give is that soil coring cannot be done below obstructions. You should point out better that excavation is better in the case of soils with a high rock content. (even stone content would not be satisfying – you say later on that you consider stones as particles > 2 mm – this would still be doable with a soil corer)*

We say, “..the depth distribution of roots is best measured by excavation, at least in rocky soils...”

*3/14 which biomass accumulation do you mean? Fine root biomass? Aboveground biomass? This is not clear.*

We added “total” to biomass.

*3/15 ... counterparts. Do you have a reference which confirms this or is this an assumption?*

Sure, and I get a science citation out of it (Yanai 1998).

*3/15 “hypothesized” may not be the correct word, since you don’t try to withdraw or confirm this later on. “Assumed” may be better.*

We substituted “speculated.”

*3/20-21 This is a strange transition. Maybe you can add a line to make clear how line 21 follows line 20.*

The sentence was rearranged to read, “Coarse root biomass is found close to the stems, and has been shown to increase in size as the stem develops (Millikin and Bledsoe 1999).” The references to predicting coarse root biomass were removed.

*4/2 This is quite an important statement in this paper. Do you know more references which confirm this?*

The statement is that root “distribution in forests may reflect the distribution of nutrients in soils rather than the arrangement of tree stems.” We do not know of others, but we added a reference later to root proliferation literature (Gross et al. 1994), which is somewhat relevant to this question.

*4/4-7 This sentence is too long and has two ‘focuses’. Maybe it’s better to make two sentences out of it.*

Done. “This assumption is implicit in the design of most root sampling studies, in that samples are randomly or systematically located, without reference to tree density. A homogeneous distribution of fine roots is consistent with the concept of root closure: if roots occupy the soil the way leaves occupy the canopy, then their density is not limited by the proximity of stems but by the available resources, which tend to be equalized by the proliferation of roots (Gross et al. 1994).”

*4/8-15 I would prefer to see the following structure: 1. What are you interested in and what are your questions/hypotheses? 2. How did you set up your experimental design in order to test your hypotheses?*

We improved the statement of the objectives and hypotheses, according to your suggestion below.

*I miss VERY clearly any sort of hypothesis on the mature stands (former agricultural land) which you sampled as well. It is not clear at all from the introduction why those two stands were included in the study and why it is even interesting to compare them with young and older stands!*

They have been removed.

*4/11-13 Ok. But then I would like to see 4 clearly distinguished hypotheses: on vertical and horizontal distribution for both coarse and fine roots.*

Our hypotheses were previously incomplete. It's even a little more complicated than 2x2, because of stand age. Now we say "that younger stands would have proportionately more fine roots, if not coarse roots, deployed at depth. Finally, we tested the relationship of root density to the proximity of trees. We hypothesized that fine roots would be more deeply distributed in the young stands than in the older stands and that the horizontal distribution of fine roots would be insensitive to the position of trees in the stand, while coarse roots would be found close to trees."

*4/14 ...in the young stands THAN in...? Unclear again.*

Changed to read "in the young stands than in the older stands..."

#### **MATERIAL & METHODS:**

*Overall: Does table 2 belong to M&M? It is not mentioned anywhere in the text.*

Table 2 is now cited in the results pertaining to soil depth and rock volume.

*Detailed:*

*5/1 When you talk about stand ages, and you call these former agricultural stands "mature" (as you did in the abstract), you should also clarify the age of these stands.*

*+ What is the difference between a former agriculturally managed woodlot and a managed forest site (as your other 6 stands)?*

These problems have disappeared with the removal of the formerly agricultural stands from this analysis.

*5/4-7 Don't you expect the species composition to have a significant influence on both total and fine root biomass, and on both horizontal and vertical spatial distribution, due to different rooting strategies?*

This topic is now addressed in the Discussion. We added a paragraph: "Some of the differences that we report between our young and older stands may be caused in part by differences in species composition rather than tree age. Species composition can change dramatically during forest succession in the northern hardwood type; for example, our young stands averaged 32% of basal area around the soil pits in pin cherry, which is short-lived and generally not found in older stands (Figure 4). Other differences in species composition between stands may be due not to successional stage but to variation in site conditions or regeneration history. Our older stands had 11 to 21% of basal area around the pits in trembling aspen, which was probably present in those stands when they were young, but was not present in our young stands. Our study design does not permit us to distinguish the effects of species composition from stand age in explaining variation in root distributions across our stands."

*5/11-13 Then why was it not part of the chronosequence?*

No longer relevant because we removed it, but the answer is that the stands in Federer's chronosequence all originated after logging.

*Table 1 - Say: sites designated with "T" and with "M" are located in the White Mountain National Forest, "B" sites are privately owned.*

The B sites have been removed, so the description gets simpler. It now says, “Sites designated with “H” are located in the Bartlett Experimental Forest; the rest are in the White Mountain National Forest.”

*Is it even necessary to use H, M, T & B? When not in the framework of the 13-stand chronosequence – where I assume the naming is originated – these acronyms are confusing.*

We have removed the site designations from the text, the figures, and the other tables but retained them in Table 1. I’ve written some papers where I omitted these designations, as they are meaningless to most readers. Then I regretted it because it’s hard to identify sites across publications based only on the age information.

- After stand age, add “(y)” Done.

- After elevation (m, add “a.s.l.” Done.

- H6/ dominant species: you forgot a comma Done.

- M5/treatment: Can you explain what TSI thinning is? Sorry. We now spell out “timber stand improvement.”

- T30/treatment: not clear: Was the stand cut in '48 or was the intensity of the cut unknown in '48? This now says “Cut in 1948, intensity unknown.”

- What I miss in this table with site description is tree density (# trees ha-1) and stoniness (%). For this paper, I think both are very important information. Do you have data on this and could you add this? Stem density is shown in Figure 3, and basal area in Figure 4. Stoniness (rock volume %) is in Table 2.

5/17 But how does this affect the description of spatial distribution? “Chosen” pit locations (non-random) do not represent the stand, I assume?

Not very many locations were rejected. We kept better records of this in 2004 and describe them in the next paper (Park et al. in review with SSSAJ).

6/3 M5 and H4 are confusing acronyms here. Can you avoid using them at all?

Yes, we can refer to the stands by age and have done so. “...except for two sites (those aged 27 and 69 years)...”

6/8 Can you explain what you mean by systematic subsampling? Which “system” do you use?

We added, “with a trowel.”

*And how big was the subsample? Have you estimated the error you induce by taking a subsample instead of washing out the entire samples?*

We added, “The size of this subsample ranged from 72 to 433 g, which was on average 1/70<sup>th</sup> of the mass of the soil.” This topic is now also addressed in the Discussion.

6/14 What was the time range of “until they could be processed”?

We added, “which was generally within two months of sample collection.”

*6/20 Again: how big were the subsamples and how much accuracy do you lose by subsampling?*

We added, “These subsamples were 1/8 or 1/4 of the remaining mass of roots.”

*7/6 Can you explain what you mean by excluding the rock volume?*

This sentence has been improved. “We calculated (i) the mass of roots per unit area, (ii) the mass per unit area per increment of soil depth, which is a measure of mass per unit volume, including rock volume, and (iii) the mass per unit volume of soil excluding the rock volume.”

+ *Why do you do so? If the fine root biomass is concentrated in so-called nutrient hot-spots (as you assume in the introduction), then maybe you should not exclude the rocks from your calculations because often right below a big rock, you can find nutrient enrichments!*

Well, that would turn up from the test we did. We wouldn’t know if we didn’t test for it.

*7/13 How do you handle the fact that the total sampling depth was different in different excavation pits/stands? (organic layer is unevenly thick + the depth until the C-horizon is unevenly thick)*

This test was done with mass per m<sup>2</sup> per cm. So although the depth of one of the layers was variable, this variation is accounted for.

*7/17-18 How did you come up with this index of tree density? Based on a book, a paper (reference??) or did you come up with it yourself?*

It is a common form of representing tree influence for aboveground competition. We added this phrase: “similar to a competition index used to describe tree neighbors (Biging and Dobbertin 1995). “

+ *Please write this as a mathematical formula (that would improve understanding!)*

Done

*7/23 What do you mean here? Shouldn’t the relation be: bigger soil volume – more roots present in this volume? Or do you mean the relation between root biomass and soil depth?*

We now say, “Correlation analysis was used to test the relationship between root biomass and soil depth or soil volume.”

*8/3 Use  $\alpha$  instead of alpha.*

Done.

## RESULTS

*Overall: Again, I miss why the results are in 6 subsections: according hypotheses? In at least the last two sections, there was no mentioning of the mature, former agricultural stands. What is the reason for that?*

The former ag sites have been removed. The subsections correspond to the hypotheses, or, in the case of tree distribution around the pits, to a topic subsidiary to a hypothesis but too long to be included in the same section without losing our readers. The importance of

rock volume and the scale of spatial variation are important to report but not worth further complicating our hypotheses.

*Detailed:*

*8/8-9 These numbers are only  $\pm 50\%$  of the numbers already given in the abstract (2/8-9). How do you explain this?*

Numbers in the results are just for  $< 20\text{mm}$  roots, but numbers in abstract includes all roots.

*8/12-13 A non-significant difference is actually no difference. Meaning that fine root biomass in the young stands does not differ from fine root biomass in the older stands. This needs to be changed in the text, and accordingly in the abstract.*

There is almost always a difference between two means, if the measurements are made precisely enough. It is therefore legitimate to describe such a difference, but it is important to consider the likelihood that the difference arose by chance. Using a cutoff for statistical significance, such as  $\alpha = 0.05$ , is one crude way to do this. We do a little better and report the P value. We also note that the difference is not statistically significant, but 0.12 might be worthy of note (88% chance that the difference did not arise by chance).

*8/17 Once again, “M5” is confusing to the reader. Either name your sites accordingly in all figures and in the entire text, but I would prefer if you would leave them out entirely.*

Done.

+ “age 28” is neither in your figure 1, nor in table 1 (with site description). I assume you mean the 24-year-old stand?

This was an error; it’s the 27-year-old stand. Correction made.

+ *What about the older stands, and what about the agricultural stands?*

Thank you for pointing out this omission. We added, “In the older stands, biomass of roots  $>20\text{ mm}$  averaged  $968\text{ g/m}^2$ .” We omitted the agricultural stands.

*8/18-20 It is not clear whether you are now talking about the young or the older stands, or the average. In the title of this section, you point out “as a function of stand age”, so please put more emphasis on the differences between the stand age classes.*

The change made in response to the previous comment addresses this, in part. We also note that coarse roots ( $>20\text{mm}$ ) are highly variable, and dead root biomass doesn’t differ by age.

*9/5 Did we expect this? Can you cite a reference on which you can base this expectation?*

We added, “This generalization is supported by an analysis of 19 published studies, which found that early successional species have proportionately more roots at greater depth (Gale and Grigal 1987).”

*9/6-9 Which age classes do you mean?*

We added, “Across all stands...”

*9/7-8 14 times – is this due to a thicker Oa horizon or do you mean relatively?*



We mean absolutely. The thickness of the Oie is not recorded because it is too temporally variable.

*9/15 (compare with 9/6) It is very confusing that you have 2 definitions for “fine roots” + (compare with 9/18) Is “coarse roots” in this case defined as roots with  $d > 5 \text{ mm}$ ?*

We changed this sentence to refer to “roots finer than 5 mm in diameter,” and the later reference is now to “coarser roots.”

*Figure 2 In the text, you talk about mature forest (= former agricultural sites) and older stands (= 55-70-year-old stands). Make sure that in the figure, you use correct and consistent terms. .*

The figure is now labeled “Age 19-27 yr” and “Age 56-69 yr”.

*+ figure caption states: expressed per unit of volume, but the actual figure says “ $\text{m}^{-2}$ ”. Why you decide to express per  $\text{m}^2$  or per  $\text{m}^3$ , does not belong in a figure caption but in the text body.*

The units are  $\text{g m}^{-2} \text{ cm}^{-1}$ . We improved the following sentence in the methods section: “We calculated (i) the mass of roots per unit area, (ii) the mass per unit area per increment of soil depth, which is a measure of mass per unit volume, including rock volume, and (iii) the mass per unit volume of soil excluding the rock volume.

*+ I prefer “different between” over “different with”, it is clearer.*

The sentence now reads, “Means within a soil depth stratum sharing the same letter are not significantly different between the two stand age classes.”

*+ you forgot to insert \*, \*\* and \*\*\* in the figure caption.*

They must have gotten lost in the translation.

*9/19-20 Again, non-significant differences are actually no differences. You cannot say “held true” unless if you describe why we should consider for example  $P = 0.12$  significant anyway. If not, please talk about trends or patterns, but not about differences.*

See comments above (8/12-13). Further, I don’t buy that a “trend” or “pattern” is more cautious a description than a difference. When comparing two things, “difference” is the best term.

*9/23 I do not understand. Are the letters in figure 2 based on relative or absolute root data? And if the relative values show less significant differences, then why did you work with these data?*

The data in Figure 2 are absolute values, as the caption and axis labels indicate. We added to this paragraph to clarify the transition between the two types of analysis. “We had hypothesized that young stands would have proportionately greater root biomass allocated at depth, after controlling for the difference in total root biomass, which was less in younger stands. To test this hypothesis, ...”

*10/4 & 11/6 Where is the difference between these hypotheses, and why are all the results of the two regarding sections not in one section?*

There is only one hypothesis relating root density to tree density. It was described before presenting the forest composition information in an effort to explain the need for stem

density information. The offending paragraph has been moved to the next section, where the hypothesis will be tested.

*10/10 use “<” and use dbh instead of “in diameter”*

Done.

*10/11-12 “many fewer” ~ less?*

“Fewer” is used for count nouns, “less” for mass nouns. No change.

*Figure 3 (# trees ha-1) and dbh, not DBH.*

Done.

*+ Please write either the stand names and expect us to know the ages, or remove the stand names.*

Done.

*10/15 Would it then not have been useful to make an extra classification “> 20 cm”?*

The figure has been much improved; thank you for your question. It now has many size classes, in stacked bars displayed on a log scale.

*10/19-23 Why is this important? When it is important and therefore interesting, I would like to see a hypothesis concerning species composition, and also the influence on root biomass (distribution).*

*Figure 4 When the species composition is not important, figure 4 is not necessary.*

Species composition is undoubtedly important, but we don’t have the statistical power to attribute variation to species differences across stands. It is important to provide the information on species composition so that interpretation, not hypothesis testing, is available to the reader. I like to think that in the future, with more information on root-shoot ratios by species, our data might be viewed in this light. This topic is now addressed in the Discussion, as described above.

*11/1 Than in the young*

Done.

*11/7 Use a mathematical formula for easier interpretation*

*for example:*

*influence of surrounding trees = sum ( $i = 1 \rightarrow n$ ) [ $(\pi * (dbhi/2)^2)/di$ ]*

*with dbhi = dbh of each of the surrounding trees within x m from the center of the pit; di = distance from tree i to the center of the pit*

Done.

*Table 3 Write “root” diameter instead of diameter*

Done.

*+ 0.45 in last column should not be bold.*

Done.

*11/16-17 Does this not belong in the discussion + what do you base this speculation on?*

It was very speculative, and it turned out to be untrue when we added more data. The statement has been removed.

*11/18 use  $\rho$*

Done.

*11/20-21 I think this is only the case if roots of all size classes have the same death rate/decomposition rate/turnover, which I do not imagine is true*

The dead roots are a mixture of size classes, and the average behavior is a combination of that of the component classes, weighted by their mass (not the mass of the live roots).

*11/22 dbh instead of “in diameter”*

Done.

*12/2-3 Do you have a reference to base this expectation on?*

We searched but found no papers describing a relation between root biomass and rock volume. Maybe this is the first!

*12/7 the, not our young and older stands*

Done.

*12/17-19 What about CV for the coarse roots within and among the older stands?*

We added: “In the older stands, the average CV within stands was 49% and among stand was 13%.”

*12/20-22 Does this not imply that soil coring might be a valuable sampling method after all, because with the same sampling effort/time, many more samples can be taken?*

We added to the Discussion: “Coring is a very efficient method for studying fine roots (< 2 mm) in upper soil horizons, but it is not effective in estimating large roots or roots in rocky soil. We cored for fine roots in conjunction with pit sampling and found that cores overestimated fine root biomass by 27 % compared to pits (Park et al. In review). Soil compaction caused a 10 % overestimate of root biomass density inside the cores. The remaining 17 % bias is presumably due to avoiding obstructions when coring. This effect could be much smaller in a less rocky soil.”

*13/1-6 How did you calculate this?*

The methods section says, “We used an inverse t-test to calculate the number of observations required to detect a significant difference, using an  $\alpha$  of 0.05.” We added Yanai (1998) as a reference, though the statistical theory is very elementary.

*13/4 young stands, not younger*

Done.

## *DISCUSSION*

*Overall: The discussion is too limited.*

The discussion has been expanded; see below.

*The mature sites were not even mentioned even though this would have been interesting in the discussion about age influence on root biomass.*

The mature sites have been omitted from the paper.

*Vertical root distribution was not discussed at all.*

Vertical distribution proved not to be so interesting. We did improve the references cited in the Introduction, as described below.

*The influence of species composition was not discussed at all. Hypothesis + results + discussion or don't mention it at all...*

This is an important issue and we now devote a paragraph to it (copied above somewhere).

*I would like to have heard something about the effect of stoniness on root biomass (distribution).*

This turned out to be not so interesting, and there seems to be no literature on this topic.

*The second part of the discussion (from 14/1 onwards) was very interesting and built up well.*

*Detailed:*

*13/8-9 This is not unexpected because your study was not set up with the goal to pinpoint the age of root closure? I also did not find this in your hypotheses...*

We added a sentence to the Methods explaining the limitation of our experimental design, as described above. "To pinpoint the age of root closure, we would have liked to excavate pits in all thirteen stands, but the expense was prohibitive. We elected to use multiple younger and older sites as replicates of two widely separated age classes."

*13/20-22 How do your results suggest that fine root biomass increases for longer than 5-10 years? You did not investigate a very young stand (5-10 years) and the difference in fine root biomass between your young and older stands was not significant!*

There is an 88% probability that the 50% higher fine root biomass we observed in our older stands is not chance but is due to their greater age, compared to our 20-28 year old stands (i.e., the P value was 0.12). This result is referred to in the previous paragraph.

*14/9-10 Please discuss better the advantages and disadvantages of the two methods! I think some studies are mainly interested in the fine roots, and soil coring (until 30-40 cm soil depth) then takes significantly less sampling effort.*

We added a paragraph to the discussion: "Coring is a very efficient method for studying fine roots (< 2 mm) in upper soil horizons, but it is not effective in estimating large roots or roots in rocky soil. We cored for fine roots in conjunction with pit sampling and found that cores overestimated fine root biomass by 25 % compared to pits (Park et al. In review). Soil compaction caused a 10 % overestimate of root biomass density inside the cores; this effect should be measured and corrected for. The remaining 15 % bias is presumably due to avoiding obstructions when coring. This effect could be much smaller in a less rocky soil."

*LITERATURE*

*Make sure that you use all correct abbreviations for journals, and cite all titles correctly. For example: Thomas et al. (2000) CO<sub>2</sub>; Global Change Biology*

We believe they are correctly cited now.

#### **CONSISTENCY & UNIT NOTATION**

*There was much inconsistency throughout the paper, and incorrect unit notation.*

*For example: g/m<sup>2</sup> should be g m<sup>-2</sup>; p=0.03 should be p = 0.03; <2 mm should be < 2 mm; 50% should be 50 %; 65° C should be 65 °C; m<sup>2</sup> should be m<sup>2</sup> etc.*

We corrected these errors and trust that the typesetting process will correct any that remain.

#### **Referee #2**

*Review of*

*“The vertical and horizontal distribution of roots in northern hardwood stands of varying age”*

*by Yanai et al.*

*Can. J. For. Res. Ms. #05-247*

#### **General Comments**

*This manuscript presents findings that hold two most interesting results concerning fine root distribution in forest stands (at least for the forest type at hand): (1) That “root closure” does not appear to occur in these stands until some time after age 60 and probably considerably later; (2) That, even in “mature” stands (near age 60) proximity to surrounding trees still has some influence on the horizontal distribution of fine roots. These are two important findings. Given the validity of the scientific approach used, and the importance of these findings, I recommend that CJFR publish this manuscript.*

*This recommendation does not come without a number of criticisms and suggestions for revision. Fortunately most of these criticisms are both relatively minor and easily correctable.*

*(1) I have some concern about the confounding of stand age and species composition in the comparison between “young” and “mature” stands. As the authors willingly point out (page 5), and as is apparent in Figure 4, the young stands have considerable *Prunus pennsylvanicus*, which is lacking in the older stands. In addition, the mature stands have considerable *Acer rubrum* and *Populus tremuloides*, which are totally lacking in the young stands. One might argue that this is merely a function of natural succession in such stands, though this argument would appear in general quite weak in this case. While this confounding is of some concern, it would still appear that age differences are the major causes of the differences in root distribution between the two sets of stand data.*

The other reviewer had the same concern, and we added a paragraph to the Discussion, which is detailed above.

- (2) *The authors describe, and include in their tables, data from two stands described as “two mature stands developed in a former pasture and woodlot.” Yet these data are rarely mentioned in the results and discussion: All comparisons are made between the 3 “young” stands and 3 “mature” stands, and appear to exclude results from the additional 2 stands. Therefore, one is left wondering why these two stands are even mentioned in this study. If there are any data comparisons or correlations that use the data from these two additional stands, it certainly is not made clear in the text. If there are, their use certainly should be made clearer. Assuming there are no truly noteworthy uses made of these data, I strongly recommend deleting their mention and the related data from the manuscript.*

They have been deleted.

- (3) *On page 3 of the Introduction and at the conclusion of the Introduction (page 4), the authors put forth an hypothesis that “fine roots would be more deeply distributed in the younger stands.” While results later described apparently refute this hypothesis, the hypothesis per se is never again referred to in either the results or the discussion. Further, the presentation of the results on a biomass per unit area and per unit depth basis (rather than as a proportion of total root biomass by depth increment for each age group of stands), does not lend itself to a precise test of the hypothesis. I recommend either eliminating mention of the hypothesis, or a more straightforward testing of it in the results, followed by some discussion. To put forth an hypothesis in the introduction and then not address it in the subsequent portions of the paper is unacceptable. Furthermore, this hypothesis is based upon only one reference that itself only indirectly implies that the hypothesis might be reasonable (i.e., Ca uptake is higher in young stands). Other references on root depth as it relates to stand age do not support this hypothesis, but have not been reviewed here.*

We now cite Gale and Grigal (1987) (see above), which supports our hypothesis.

- (4) *The paper is somewhat artificially separated into two sections, “Results” and “Discussion.” Because the “Results,” as currently written, contain considerable discussion themselves, I strongly suggest combining these sections into one “Results and Discussion.”*

I prefer papers that have separate Results and Discussion sections, because this organization helps readers who want to skim the paper. The Discussion section has been expanded and improved.

- (5) *The conclusions reached concerning the age at which “root closure” is obtained are very important ones, yet they are not mentioned as such in the abstract. I recommend some mention of this conclusion in conjunction with the results upon which it is based. This conclusion is far more novel, interesting, and important than the rather obvious finding that fine root biomass declined with depth (which takes up a portion of the abstract)!*

We added to the abstract, as described below.

*Specific Comments*

*Title:*

*While accurate, the current title is not one that tends to grab the reader's attention. Also the importance of the findings relating to the age of root closure are far from apparent in the current title. I suggest the author's search for a more "enticing" and, in some sense, illuminating title. Unfortunately, I must admit that I could not come up with a good suggestion myself.*

If someone along the line can think of something catchy and accurate, we'll consider it.

*Abstract, line 9: The sentence should begin with the word "mean": "Mean total live root biomass..."*

Done.

*Abstract, line 10: Fine (<2 mm) root biomass was 1.5 times greater (Not "fine roots were greater").*

Done

*Abstract, line 11: This would be a good place to describe conclusions about the age of root closure in these stands.*

We added, "suggesting that fine root biomass continues to increase past the age of canopy closure in this forest type."

*Abstract, line 11: The authors are referring here to "root biomass density," I believe, and not "root abundance." The latter term would refer to the number of individual roots or root branches or tips, rather than the biomass that has been discussed in the text.*

Done.

*Page 3, line 4: It would be most interesting to know the range of ages at which Vogt et al. found fine root biomass closure to occur. The ages reported for root closure in the other references here (and in the Discussion—especially Page 14, lines 13-23) seem very young.*

We simplified the sentence to read, "In Douglas-fir stands, fine root biomass peaks at the time of canopy closure (Vogt et al. 1983)." This paper compares 11-14 yr old stands with 33-49 year old stands, so it has no better resolution than we do at identifying when root or crown closure occurs.

*Page 3, lines 5-6: The statement about increases in coarse root biomass needs a reference.*

There is none, which is why we say "presumably." The next sentence says that this has yet to be described for northern hardwoods. We did add a reference (Fahey et al, in press) for the aboveground biomass.

*Page 5, lines 15-17: It is unclear what is meant by "located in three strata in each of two spatial dimensions." Please clarify.*

The sentence now reads, "The measurement area in each stand (generally 50 m by 50 m) was divided into nine cells, and three cells were randomly selected such that no two were in the same row or column."

*Page 6, lines 5-11.: This is surely a result of my version of Acrobat Reader not being able to handle subscripts and superscripts. But, in case it is not a problem on my end, the “a” in Oa and the “ie” in Oie should be subscripts.*

Is this true in the Canadian system? It can't be; I think you use L, F, and H. We use Oi, Oe, and Oa.

*Page 6, lines 5-11: Why was the Oie air-dried? Was this just a procedural error?*

We added, “which is difficult to sieve when moist.”

*Page 6, lines 16-17 Since the Oie was air-dried and it was therefore impossible to separate live from dead roots, how was the live root biomass determined? The resolution of this problem should be described in the Methods.*

The Figure caption has been improved to say, “Dead roots were included with live roots in the Oie because this layer was dried before subsampling.”

*Page 6, line 14: How long were the roots refrigerated prior to processing? Was there any problem with decomposition during refrigeration that might have affected biomass determinations?*

We added, “which was generally within two months of sample collection.”

*Page 6, line 14: When you say that roots were separated live from dead based on coloration (i.e., “darker”), are you referring to the exterior color or the color of the cortex? In recently dead roots, especially larger diameter roots, it is necessary to examine the color of the cortex to separate live from dead.*

We meant the exterior color. The sentence says, “Dead roots were recognized because they were more brittle and darker in color than live roots.”

*Page 7, top of page: Please describe in more detail the sub-sampling procedure.*

We added, “These subsamples were 1/8 or 1/4 of the remaining mass of roots.”

*Page 8, lines 10-11: Here it states that roots 5-20 mm in diameter had 2.7 times more biomass in the older stands. The abstract states that roots 2-20 mm in diameter had 2.7 times more biomass. Which is correct?*

Both are correct, but we don't want to include numbers in the abstract that are not in the Results. We added to the results: “Similarly, biomass of 2-5 mm roots was 1.3 times greater but not statistically distinguishable between young and older stands ( $P = 0.15$ ).”

*Page 8, lines 11-12 and line 16: It would be more accurate to state that root biomass was greater than to say that roots were more massive.*

Done.

*Page 8, lines 8-10: One assumes that the data presented here are per unit area. But it would seem to be a good idea to clarify this fact here. Similarly, throughout the paper, please be clear as to whether results are expressed on a per unit area or per unit volume basis.*

We use the units of mass per area (g/m<sup>2</sup>) in this section. These units are readily scaled to the landscape.



*Page 9, lines 7-8: Here it is stated that the Oa has 14 times the root biomass as the Oie. It should be made clear that this is on a per area basis it it is (I assume it is [?]). It would be useful to insert here information on the results of the same comparison on a per unit volume basis (i.e., root density).*

Unfortunately, the irreproducibility of depth measurements of the Oie limits the value of comparisons based on volume. We do not even record the depth of the Oie, as it depends on how you hold the sample, or if you don't touch it, on whether a leaf is lightly balanced at the top. We added a sentence to the Methods section to make this clear.

*Page 9, lines 8-10 and line 18: Please replace “upper B horizon” with the appropriate mineral soil depths. With the exception of the O and C horizons, all root data have been presented in terms of mineral soil depth until now. There has been no information presented about other soil horizons or their relationships to depth. Furthermore, the data were not collected so as to provide information relating roots to other horizons.*

We added a reference to Figure 2, which shows the depths. “Upper B” is intentionally vague, because depending on the size class, it could be 0-10 or 0-20.

*Page 9, lines 11-13: Does this statement about percent distribution by depth refer to all 8 stands; if not, which ones?*

We added “across all six stands.” Two stands have been dropped from the study. We made a correction to the percentage (from 35 to 34%) consistent with this change to the data.

*As an aside, I can't help commenting here that I hope no one would take seriously any study that sampled root biomass by only coring to a 10-cm mineral soil depth!*

We report the root biomass below 10 cm and also below 30 cm in the mineral soil. The range of depths used for sampling with cores is 10 to 50 cm (Park et al, in review).

*Page 14, lines 1-8. In the introduction a number of studies are mentioned that have “asserted that fine roots are not sensitive to distance from trees (Millikin and Bledsoe 1999, Leuschner et al. 2001, Eamus et al. 2002”—as well as Gross et al. 1993). Information from these references would be most useful at this point in the discussion, for comparison purposes. For example, some discussion of why the results in this study might differ from those in these studies or other studies in the literature would enhance the paper.*

Having added a second set of 18 pits to our analysis, we now have our own differences to discuss. We added a paragraph to the Discussion. “It is puzzling that although roots < 0.5 mm and 0.5 – 1 mm showed the effect of tree proximity in the 18 pits studied in 2003, in 18 additional pits studied in 2004, the roots in a combined 0 – 1 mm diameter class showed no such pattern. The difference is important, because fine roots are more often studied than coarse roots, and a sampling method that ignores the position of trees would be satisfactory for a study of fine roots, were they randomly distributed. There were other differences between the 2003 and 2004 samples, which shed some light on uncertainty in root sampling using the pit method. The method of subsampling the sieved soil in the field for later root picking is very important, because the subsample is necessarily a very small fraction of the total (1/70, on average, in this case), and so minor errors are magnified in scaling up to the pit. We measured 72 % more fine root biomass

(< 2 mm) in 2004 than in 2003, which might be associated with an improvement in subsampling tools from trowels to tongs (Park et al in review). Alternatively, there may be changes in root biomass of this magnitude between years, due to differences in environmental or biotic conditions affecting carbon gain and allocation to roots (Farrish et al, 1991). Our study design does not allow us to distinguish differences in methods from differences associated with the year of the measurement, in this case.”

*Table 1.: It would be helpful here to include the % basal area occupied by each dominant species in each stand, or at least to refer in the Table heading to the additional relevant information of this type contained in Figure 4.*

We added, “Stem density and basal area by species in the areas around the pits are available in Figures 2 and 3.”

*Also, please spell out in full “TSI” thinning in the table proper.*

Done.

*Table 3.:*

*A more complete table heading would read “Root Diameter (mm)” rather than simply “Diameter (mm).”*

Done.

*Figure 2.:*

*When it is stated in the figure heading that “root biomass is reported per unit volume of soil, because the strata differed in thickness,” may we presume that the soil volumes used excluded coarse fragment content? If so, should not that sentence end with “...because the strata differed in thickness and in coarse fragment content”? If not, then some wording should indicate more accurately exactly how the root biomass is reported in this figure.*

We changed the sentence to read, “Root biomass is reported per unit volume of each stratum...” “Soil” is an unfortunate term because it can mean the <2mm fraction. We used the “thickness” of each stratum for our measure of volume.