AHolland review of "Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products" by Jared Nunery

Several forestry management regimes were analyzed with respect to C sequestration that ranged from differing levels of harvest frequency and harvest intensity. The authors found that unmanaged forests had the highest mean C sequestration and the forests with the highest intensity of management had the lowest sequestration rates.

As this paper fills in a current gap in carbon research, this paper should be accepted to the journal of Ecological Applications. I think this paper follows the journal's guidelines in providing research that is applicable to a variety of disciplines as pointed out in the paper (forest managers and C accounting).

The abstract and introduction are well written and provide the necessary information for the section. A good job was done in providing background information on both the forest manager side and the ecologist/carbon researcher interests. For the methods section the second paragraph of the simulations descriptions (start on line 224, pg10) can be a bit confusing during first review of the descriptions. Although the previous paragraph described 8 active scenarios separated into 4 even-age and 4 uneven-age scenarios. The first sending on the next paragraph just lists "the 4 active management scenarios were run under 2 different harvest intervals, 1 long and 1 short." So if one is just looking at the numbers and trying to add things up it doesn't work. The next sentence is then the tie describing the 2 structural retention scenarios. I would suggest structuring this whole paragraph similarly where you clearly state that each set of the scenarios (even /uneven age) were subject to different management scenarios. Next describe the first type and its 2 levels, followed by the 2nd type and its corresponding levels.

As there are several faucets to this paper beyond the two hypotheses given, I think it is key to have the results and discussion section divided up with clear subsections on the material addressed. This is a good layout and really helps guide the reader through the original analyses and additional justification work done. Some of the material from the methods section is then repeated in the results section such as the description of the sensitivity analysis scenarios starting on ie 340 of page 15. Although more detail is provided in this section than the results, it could be fully explained in the methods section and then abbreviated here in the results. This suggestion is to help keep the results section a statement of findings and not have the reader feel that new methods are being introduced. I think the "model assumption" section from the discussion could be moved to the methods section as it is mainly written to justify/clarify the parameters used in the study. It could be moved to the paragraph on page 11, line 242.

I will not comment on the current version of the figures and tables as I think once the stated versions are reproduced they will effectively convey the information.

Joe Bartlett

2/25/09

Review of Nunery and Keeton

The purpose of this article was to describe the effects of harvesting frequency and intensity on carbon sequestration in forests. Numerous other studies have modeled similar scenarios and have produced conflicting results as to whether even age intensive harvesting scenarios or uneven low intensity scenarios sequester more Carbon. This study also included C storage in wood products produced from harvesting, which is an important variable not calculated in several similar studies. The USDA FVS model was used to predict C sequestration for 32 sample plots in New England over a 160 year study period. They found that the control treatment (no harvesting) sequestered the most carbon and that carbon sequestration decreased with increasing harvesting intensity, even with the inclusion of C storage in wood products. These findings have significant implications with the growing market for carbon credits through C sequestration in forests.

With the exception of a few instances of weak wording (on one hand, on the other hand) the paper is well written and does a good job describing the very extensive modeling process and results. The abstract is a great summary of the study. The introduction contains a thorough literature review but would benefit from better organization and a paragraph or two at the beginning with more basic background information. These paragraphs could include basic information on forest carbon dynamics, pros and cons of the different harvesting intensities, and other general information. The purpose statement and hypotheses could be clearer, bullets might help with the hypotheses. The methods section is good and clear. The results and discussion section both contain methodology sentences that either belong in the methods section or are redundant with previously described methods. The results are described well, a table presenting the significance levels of the different statistically tests might be helpful. The Discussion section contains some very good inferences, but there is also a large amount of redundancy with the introduction. It is clear that there are differing opinions within the forestry community as to the best management scenarios for C sequestration, you need to make it clear whether your results are supporting or challenging the most commonly held view within your field. I like the carbon market discussion section but it needs to be mentioned in the abstract and introduction. The conclusions are good and concise but you definitely need a good synthesis sentence to wrap-up the paper.

This paper should be accepted to Ecological applications with major revisions. It meets the criteria for journal submission, however I think a more forestry specific journal may be a better fit for this study. The submission guidelines are clear that papers should be aimed at a general scientific audience and should be innovative or unique. Your study is very important but it is more designed to improve existing information and it is definitely aimed at an audience well versed in forest modeling. Specific recommendations for improvement are as follows:

- L63 watch tense
- L64 “business as usual” has not been described
- L70 Purpose statement needs to be reworked
- L94 awkward sentence and your however statement refers to the same idea as the first half.
- L101 Somewhat jumps the gun on your purpose statement
- L110 Can you give an example of these emissions benefits

- L129 This sentence is confusing
- L155 need to make this a clear purpose statement
- L188 this paragraph belongs in the introduction
- L340 This sentence belongs in methods
- L406 Reword this sentence to be stronger
- L407 Most of this first paragraph is covered in the introduction and could be condensed to 1 sentence
- L461 Introduction
- L470 Results
- L520 Methods?
- L606 Need a good wrap-up sentence to conclude paper

February 25, 2009

UVM internal review of:

> Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products
>
> Authors: Jared S. Nunery and William S. Keeton

This paper evaluates the amount of carbon that can be sequestered using northeastern hardwood forests as a carbon sink. Initial data from 32 Forest inventory and Analysis plots were collected for this simulation, with all plots being composed primarily of northeastern hardwood species with relatively low mixed conifer levels. Using the initial data collected from these plots and the USDA Forest Vegetation Simulator was used to model the amount of carbon sequestration possible for the plots over a 160 year time span. 7 separate simulations were run to show the amount of carbon sequestration using different management practices with the assumptions of an unchanging climate, known uses of forest products from each type of management, and not accounting for a reduction in carbon emissions by using timber products over conventional building practices. Of the 7 simulations the control of no cutting showed the highest levels of carbon sequestration over the 160 year time period. This report also showed that less intensively managed forest sequester greater amounts of carbon than with more intensive practices. Uptake rates of carbon were also noted between the 7 management schemes showing that the no managed forest had a relatively high rate of sequestration but areas that were clear-cut had higher uptake rates due to the fast rate of regeneration in young forests.

This paper shows a great deal of information that is pertinent to making important forest management decisions. The important of this report will be of increasing value due to the developing carbon credit markets. Additionally the information and modeling processes used in this report come from data sources that are readily available allowing a similar approach to modeling to be conducted across a wide geographic range through different ecosystems. The quality of writing in this paper is quite good making understanding of the process and considerations necessary to conduct this study easy to understand for the lay person. That said the organization of this paper needs improvement in order to reduce the need of cross referencing for the reader.

This paper shows a mechanized approach to determine which forest management practice may provide the greatest amount of carbon sequestration for any given ecological region where forest inventory , and growth characteristic data is readily available. This is also displayed in this paper in an informative way allowing any person with some knowledge of the subject to perform a similar analysis. However the organization of this paper needs to be improved to allow for rapid assimilation of this knowledge. For these reasons I believe that this paper should be accepted with minor revisions.

- Over all the results section of this report is quite comprehensive however it often seems to restate items that were mentioned in the methods section of this report. It seems like the details on how the data will be presented could be easily be moved to the methods section. As the introduction of this report is well written those who read this paper will have a general idea of what is expected to be presented in the results section of the report. If a simple table is used to show the abbreviations used to describe which management type is which little other information will be necessary in results section as figure 2 pretty much says it all.
- In this paper I found it quite nice that forest products were taken into account for. Personally I like seeing all the details presented in one place, but I would like to know more about the modeling of the forest products. I would assume that the type of product that can be extracted from each type of forest management practice would be quite different , as it can range from pulp products to large structural timbers. Although briefly touched upon briefly with the scope of the journal you are submitting to some more details may need to be included to inform the audience that is familiar with broad applications. This would allow the reader to uses their own intuition in understanding the carbon emissions savings associated with changes in saw log vs. pulp log production. If a small table showing the ratio of proportion of a select log type were included in this paper it would encourage the reader to look at the broader implication of forest management type.
- One item that struck me as odd when reading this paper is the location of the assumptions at the very end of the results section. This is one section that can easily be pushed up to the methods section of the report. If this were done the reader will understand how to interoperate the results before reading them as oppose to only fully understanding how to interoperate them after reading to the end of the report.

Best of luck with your submission,

Jaron

Lee Corbett
GEOL 371
2/25/09

Review of: Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products
Authors: J. Nunery and W. Keeton

In this manuscript, the authors present data from a study that assesses effects of different forest management plans on carbon storage. The authors use 32 FIA plots distributed across New England and apply different harvesting treatments to these plots through a Forest Vegetation Simulator. These treatments include a variety of harvesting frequencies and incorporate information about carbon fluxes from forest biomass and wood products. The results suggest that the "no harvest" treatment performed best at carbon sequestration, and that those treatments with lower harvesting frequency performed better than those with higher harvesting frequency.

Overall, the manuscript is well written, thoroughly researched, and enjoyable to read. It does an excellent job providing the necessary background information, and I was able to understand and appreciate the value of the research despite my lack of familiarity with the topic. The authors do a good job of laying out clear hypotheses and then returning to those hypotheses as they present and interpret their results. Statistical backing strengthens the research immensely, and all of this quantitative information is presented in an accessible fashion. The writing is clear, professional, and polished.

Please refer to the hard-copy edited version of the manuscript for small comments regarding structure and rhetoric. In addition, I have several broader comments:

1.) Can you reword your title slightly? The "including wood products" is a little bit confusing grammatically. What about something like "…including the role of wood products" or "…including the impact of wood products".

2.) Your abstract is very good, but it feels too long. Is there anything in there that you can cut out? If someone wants to spend a minute reading your abstract and getting the feel of your paper, the length is unwieldy. Cutting out a few sentences with specific pieces of information (e.g. the sentences that span lines 37-39, 40-41, and 44-47) might help.

3.) This question might be due to my ignorance in the field, but it seems like harvesting (and all of the related machinery to build the roads, cut the trees, skid the logs, process the wood, etc) is a very fossil fuel intensive process. Should this play some role in your analysis? I doubt it's something that you can quantify, but it might be worth mentioning that there would be a lot of added fossil fuel use associated with each harvest. How do other studies deal with this issue?

4.) In your discussion, you mention that you chose to hold climate characteristics constant throughout the duration of the 160-year modeling period. I certainly understand why this is, since we can't yet create reliable climatic predictions for those time scales, and I think it was the right choice for your work. On the other hand, though, this assumption is completely unrealistic since

climate will undoubtedly change over the next 160 years. Maybe this is worth some discussion in your manuscript. For instance, how would climate warming affect forest growth and harvest? How robust are your models to climate change? Would it even matter to your conclusions? If so, what aspect(s) do you think would be unreliable with changing climate?

5.) I think your manuscript would greatly benefit from adding a short conclusions section. Your paper as a whole is pretty long, and you cover a wide range of information. Adding a short section (only a paragraph) to sum it all up might help the reader feel like he/she got more closure. Additionally, adding a section at the end would make life a lot easier for those who only want to read the abstract and the conclusions.

Good luck with edits and publication. Well done!

Lee Corbett
abcorbet@uvm.edu

Paper Review by Carrie Pucko

Authors: Jared Nunery & Bill Keeton

Title: Forest Carbon Storage in the Northeastern US: effects of harvesting frequency and intensity including wood products

Summary:

This paper discusses the role that forest management strategies have on carbon sequestration in the Northeast. It is a region without as many detailed studies as they have out west, and studies that have been done have focused either on rotation time or harvest strategy, but not both. In addition, this paper takes into account the carbon stored in wood products post-harvest. The results of this paper show that no management of forests is the best way to store carbon due to the accumulation of CWD over time, however, in managed forests, uneven-aged forestry practices sequester more carbon than even-aged forestry practices such as clear-cutting or shelterwood cuts. The management practice (even vs. uneven-aged) is the best predictor of carbon storage in NE forests, however, within each group, rotation time is also significant. The impact that wood products have on carbon accounting can be important, particularly in intensively managed stands with low retention and short rotation times, since without the inclusion of wood products, these stands are modeled to be carbon sources rather than sinks. These results have impacts for land managers and are likely to become more important as carbon markets need to predict carbon sequestration for credits.

Review:

Let me say first of all that I think Ecological Applications is the perfect journal for this type of article. I think it has clear relation to people's lives, particularly as I said before with the likely formation of carbon markets. Also, I think that since the journal tends to be pretty data-heavy, the amount of information you have in your tables and figures is alright. I think you've made the case well for this being a novel study and one that incorporates interactions that are important and can be put to use here in the Northeast. There were however, a few points or concepts that I had trouble following, at least initially, which I will discuss below.

Title: While I think you've got all the main points covered in your title, the "including wood products" reads a little awkwardly to me. Perhaps, "The effects of harvest frequency and intensity, and wood products on carbon storage in the northeastern United States"?

Abstract:

I think the abstract is well written, just a little long. I tihnk that you do not necessarily need to include the bit about leaving emissions out of your carbon calculations. I think that's something that would be fine to leave for the methods. Also, I was confused after the abstract about how exactly wood products were fitting into this study. By the end of the paper it made sense, but I think you should clarify a little bit why it is necessary to include them in this study.

Intro:

I think that this section was well written but again perhaps a little long. The first paragraph of this section I though was very strong, concise and incorporated all the key points I would have wanted to be there. The only minor problem here was that I don't really understand the phrase in parentheses in line 68. I thought you had a good description of past work done in this field on page 5, but that it would have been great to have that information summarized in a table per haps with columns: 1) management scheme 2) Carbon Storage /yr. 3) citation. On page 7, I thought that while helpful, the extent to which you detailed all the forest models may not have been necessary. Overall, nicely done and I thought your objectives were well established.

Methods:

I followed your methods much better than I thought I would but I found myself wanting one additional piece of information. I wanted to find out more about the FIA plots. What data were collected in them? Were they experiencing these different management strategies or were they all old growth? Did you do any of the collecting or monitoring yourself or did you just model the FIA data you acquired? My only specific comment on this section is that there is some funny wording on line 256 of page 12.

Nothing major. One more general question though was, how did the slash that was either removed or left on site factor into the carbon calculation? If it was taken away, was it assumed to have been burned and did it factor in that way? Or was it left out of your calculations? Would this have changed your results?

Results:

My only request in terms of results is that you put all of the simulation means reported on page 14 into a table. I think it would be very effective. Other than that, I thought your results were clear and well reported. I wasn't dying to have anything else here.

Discussion:

I thought that your conclusions here were straightforward and logical. I think that you show how important taking both rotation time and harvest intensity are in managing for carbon. The only thing I don't think was addressed quite well enough was that what is done with the trees after they're taken out of the forest matters a lot, at least I think it does. Is there a difference between trees that are made into furniture as opposed to paper? How can we tell what goes where and how long it stores carbon for? Could you include a statistic about the percentage of wood that goes to each in northeastern forests? I'm sure it's very different out west. The only detailed comment on this section was that I got to the end of the paper and didn't know what the regeneration inputs were. I'm assuming they're input parameters for the model, but I'm not really sure.

Forest carbon storage in the northeast United States: effects of harvesting and intensity including wood products

02/25/09
Review by Christina Syrrakou

This paper presents how various parameters may affect carbon storage in forests in the northeast United States. The parameters analyzed are mainly the frequency of harvesting and the degree of post-harvest structural retention. The writers use modeling including nine possible scenarios and statistical methods to test the modeling results. The aim of this study is to address forest managers and policy makers and provide them with knowledge of the effects of forest management on C sequestration. Finally, the writers conclude that passive management sequesters more C than active management and that management practices favoring lower harvest frequencies and higher structural retention sequester more C than intensive forest management.

The paper is carefully written and in formal language. Also, it is obvious that the specific study was time consuming and required a significant amount of work in the background. This can be seen by the variety of data provided, the various methods used (statistics, modeling) and the different scenarios which provide various combinations of the parameters under study. For that reason, the readers of this paper are provided with a large amount of information. My main problems with this paper where caused by my lack of specific background since this paper includes a lot of technical terms which are not further explained. Although I believe that it is up to the writer whether they prefer to make this paper accessible to a broader audience or not, I found myself troubled with some important concepts. For example what is the difference between even and un-even aged scenarios and what do you mean by C uptake?

More specific in terms of context, I think that the introduction was well-written providing the reader with general info and some specific details of the current study. Also, the study area and the model description were well presented. The part that I found most difficult to follow was the data analysis which for me contained a lot of unknown words and a big amount of information. The discussion part was more comprehensible. As for the conclusions, I feel that they summarized well all the important points that the reader has to remember after reading this paper.

In addition, I think that a very strong point of this paper is that the writers repeatedly presented concepts of previous studies and how the specific study contradicts or agrees with them. Actually, I think that you could create a whole different section gathering this info.

So, in conclusion, I recommend that this paper should be published with minor revisions. Some points that I think should be revised are:

-l.196 When you refer to five years resolution you mean that the total time for the model is 160 years but the results are obtained for every five years?
-l.306 What do you mean by clear gradient?
-l.369 You mention Table 4. Maybe you need to rearrange the tables so that they appear in the order that they appear in the text.
-l.390 Although the three different ways of C uptake calculation exist in the table do you think you could add them here too, in order to help the reader?
-l.520 Should the model assumptions be stated in a former part of the text, perhaps at the beginning of the section?
-The fact that Table 1 was not very clear didn't help me understand the different scenarios.

Finally, as previously mentioned, I believe that this paper presents a serious work and therefore some clarifications and rearrangement of the large amount of info could make it accessible to a wider audience and strengthen its quality. I hope I helped and wish you good luck!

Review of

Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products

Jared S. Nunery

This paper looks at carbon sequestration in hard wood forest in the the northeast US. The purpose is to determine if unmanaged forests sequester more carbon then managed forests. The thought is that managed forest grow faster and trees removed to be turned into lumber or other products that sequester the carbon long term. This project is important because it allows us to understand if is better to manage a forest or let it grow on its own for sequestering carbon and selling carbon credits. The project discovered that forest sequester more carbon the less they are managed.

This paper, from what I can tell, has data that is of high quality and reproducible. The interpretations make sense but I think there need to be more work looking at properly managed hard wood forests and their potential for sequestration. For the most part the writing is very clear, but occasionally sections are poorly explained and hard to follow. The figure are good, the last one is a little hard to read and the captions I think need to contain more detail.

I believe this paper should be accepted with revisions. The paper should be accepted because it adds a much better understanding to forests and their sequestration of carbon. This currently is a be topic but will become much large if the national government starts a carbon credit system. There are a few things that could be improved though.

1. For me it would be easier to read is C was replace with “carbon”.
2. Some portions of the paper need to be better explained to be accessible to all audiences.
3. I think this paper is running the danger of being to long. This length may be the norm for the journal you are publishing in, but for me personally I felt it was a little long.

The paper seems to be compliant with all the rules, as far as I can tell.

Charles Trodick

Eric Portenga
Writing Seminar
2/24/2009

Nunery and Keeton Review

I found the content of this study along with the results it produced to be extremely informative about an area of the commerce market I know very little about: deforestation methodologies and their impact on the carbon market. This study compares various methods of sustainable deforestation and their capacity to sequester carbon from the atmosphere. Methods in which the forests are allowed to develop on their own with no cutting/removing of timber sequester the most carbon whereas the clear cutting techniques have the highest carbon uptake rates. When the carbon sequestered in wood products taken from the tree stands were added into the model, the sequestration of all three types of scenarios increased. The addition of wood products into sequestration models accounts for a large previously ignored carbon sink. The forest management scenarios provide the most complete guidelines for loggers interested in doing their part to mitigate the effects of climate change while maintaining sustainable practices and making their trees work for them as well.

This study ties in perfectly with the Mission Statement provided by *Ecological Application* in that the methods and techniques used in this study can be directly applied to forestry management to support environmental decision-making. As this paper ties in so well to the journal's goal and targeted audience, I would approve it for publication. The manuscript has a good flow from section to section and the text of each section is true to its heading. I think the author has done a great job keeping discussion out of the results and integrating the results into

the discussion. The methods are clearly represented in the tables as are the data in the figures. Some things about the manuscript, however, should be looked at before submission:

- The terms “even-aged” and “uneven-aged” are used many times throughout the paper, but never clearly defined. It’s possible the target audience already knows about these classifications, but they might not. If that is the case, I would suggest mentioning what these terms are early on in the paper.
- The paper seems to be heavy in regards to quotation mark, comma, and hyphen usage. I would go through and eliminate any instances where it is not completely necessary.
- Along the same lines, I have always been discouraged from starting sentences with “However” and counted ten instances of this. I think the sentences could be written without starting them this way and without losing their meaning, even if that word is moved into the interior of the sentence just a little bit.
- One of the larger issues I had was that it seemed as if the study attempted to tie itself in with the current climate change crisis, by finding a forest management method which would sequester the most carbon. This finds the most effective way of keeping a forest producible while allowing it to be the strongest of the scenarios in mitigating the effects of climate change. On page 25, the “Implications for forest management and carbon markets” section starts off by saying that the contribution to carbon sequestration by forestry techniques is small relative to other means. Even though the significance of the results from the study is defended soon after, the big picture scheme of the study seems to be downplayed by that initial statement. The fact that carbon sequestration in forests isn’t as contributive to the sequestration efforts as a whole is irrelevant to the main focus of the

study, which is determining which of the forestry management methods contributes the most to carbon sequestration.

- In the discussion about the CART model, the scenarios are delegated letters A-I; however, these delegations are not used to mention the nine scenarios elsewhere. I believe this was primarily for use in the CART model, but I'm not sure. Maybe a few lines explaining this would clear up some confusion. In Figure 4., even though I know B-I are active management scenarios, F and G are separated from the other scenarios, but neither the figure caption nor the text says why and which scenarios these refer to.

Paper Title: **Forest carbon storage in the northern United States: effects of harvesting frequency and intensity including wood products**
Paper Authors: J.S. Nunery and W.S. Keeton

Reviewer: **Lance E. Besaw**
Date: Feb 25, 2009

Summary
The authors study the effects of different silvicultural systems and their impact on forest ability to sequester carbon. In so doing, they simulate the sequestration of carbon under several plausible scenarios. They found that leaving the forests alone allows for statistically significantly greater amounts of carbon to be stored. The results of this study are important from a forest management standpoint and are of particular interest in light of future carbon trading strategies currently under consideration by numerous companies, states and institutions.

Evaluation
Regarding the data quality. The data collection and analysis methods appear to be very thorough in the authors' attempts to cover the range needed to validate their study. However, I am not an expert in the field and cannot provide further comment on the data quality.

For the timescale of focus in this paper, how might impacts of climate change affect the outcomes of the models and interpretations? Are there further implications with the release of methane? Can the simulations incorporate this, as Methane is 20 times more potent greenhouse gas than CO_2.

Overall the figures present god material to the reader. However, I wonder if all of the information presented in the tables is necessary for the readers to understand and accept what the authors are presenting?

Recommendation *(and justification of whether the paper should be accepted, accepted with major revisions, or rejected)*
Overall, I think the manuscript is extremely well written and it contribution is significant. I recommend the manuscript be accepted as is. Only minor revisions might be needed to address these points.

Specific Comments
I feel like the introduction is too long and contains too much background material. Much of the material contained within this section is very important to the authors work but might fit better into a background/literature review section. Keeping this information in the intro presents the reader with too much material and can take them away from the contributions of this particular work.

Table 2 is very large. Is all of this information necessary for the reader to comprehend what the paper is about? Can this be reduced or can this be added as supplementary material?

The Data Analysis section is extremely well written and provides the reader with just enough information about the statistical techniques to understand how they are used in the paper.

The Results section does a good job presenting the reader with the simulation results.

Lastly, the manuscript does seem to be very long. I wonder if the authors could tighten some of their arguments and shorten the paper to really hit home its contribution.

Luke Reusser
GEOL 371
February 25th, 2009

Review of:
Nunery, Jared and Keeton, William, **Forest carbon storage in the northern United States: effects of harvesting frequency and intensity including wood products.**

For Submission to:
Ecological Applications.

In this manuscript, the authors report their findings from a study investigating the effects of different harvest frequency and management intensity scenarios on C sequestration in 32 temperate forest plots located in the northeastern United States (ME, NH, VT, and NY). Amongst other pursuits, they test two fundamental hypotheses; 1) unmanaged (or unloged) forests will sequester greater amounts of C than actively managed forests, and 2) forest plots subjected to decreased harvesting frequencies and increased structural retention will sequester greater amounts of C. The authors use the Forest Vegetation Simulator to project stand development over a 160-year period, longer than the longest harvest rotation. In short, they find that indeed, if you leave a forest alone, it sequesters more C, supporting their first hypothesis. Similarly, greater amounts of C are sequestered with lower frequency harvesting and increased structural retention, supporting their second hypothesis.

Overall, this manuscript is very well written and quite solid. The figures obviously need to be finished/created/cleaned up. Addressing the fluxes of carbon in today's world is of obvious and great importance, and optimizing forest management for maximum C sequestration is potentially a very important piece of the puzzle of addressing climate change in the coming decades. As such, this manuscript presents findings of real world application and warrants publication after some modest revision.

There are two somewhat big picture items that I would suggest addressing in order to strengthen this manuscript. First, and I know that you said it had a major revamp just before you handed it to us, but there appear to be some organizational issues. Particularly in the results and discussion sections, I kept finding material that read like it should be in the methods. Second, and I know this is probably due to FVA limitations, but I found it rather alarming that climate was held constant over the 160-year period. Forests really aren't anywhere near my field, but seeing as the part of the motivation of this research is to help ameliorate some of the effects of our changing climate, I think you at least need to discuss how warming temperatures and changing weather patterns could affect your model results. I know you can't get quantitative, but maybe a brief sub-section discussing some end members.

Below, I have listed key suggestions by section. Refer to the actual manuscript for smaller more detailed corrections and suggestions.

<u>Abstract:</u>

- While you do a very good job of justifying the importance and motivation of your research in the introduction, I think a little bit of this needs to come out in the

abstract too. It sets the stage, and could even be the first sentence…the why bother.

- Other than that, I think it reads quite well. My only other suggestion would be that I noticed you fluctuated back and forth between active and passive voice. It would flow better if you stick to one, preferably active.

Introduction:

- While I was very impressed with all the information in the introduction, which successfully explained why this is important and how it is such a complex field of study, it is rather long at the moment. You may be able to distill with some reorganization and focusing on the stuff you really go after in the rest of the paper. I caught a couple of redundant paragraph sections in the later part of the intro.
- You did a great job stating your hypotheses and ending many of your paragraphs with "in this study…" statements clearly laying out how you will address specific and relevant issues.
- Being rather suspect of complex models, I was curious about comparisons. I understand that you are looking at relative differences between your plots, but I couldn't help wondering how realistic the FVA model is. Is there another model that can accomplish all the things you are trying to address so you could have some cross-model comparisons? I think it would strengthen the application of your findings to other locations.

Methods:

- Most of this stuff is way out of my field, so I will take your word for it. My one big issue here, as stated above, is that it is completely unrealistic to hold climate constant over the next 160 years. I don't really know how you should address this shortcoming.
- What is "Cost-complexity pruning?"

Discussion:

- In several places, you used the S-word… "significant," but didn't back it up with anything. Knit-picky, but maybe tone down to "substantial" or the like.
- P. 20, ln 449-450. I got a little confused with this statement. Do you mean you can't look just at frequency because you see different things in even vs. un-even aged stands?
- P. 21 and 22. A lot of what you have written here sounds like methods. I'm curious why you chose to include it here.
- P. 23, first graph. When you talk about wood products as storage, do you factor in the reverse as well? If every year, so many tons of C are made into tables and houses and the like, some amount of wood product is retired…houses condemned and dismantled, broken tables discarded and the like. Is this where the landfill part comes in? I'm just having trouble following the fluxes.
- P. 23, Model Assumptions: For starters, this is another one of those sections that seemed like it belonged in methods. Second, I have to harp on climate being held constant again. It may be necessary for the modeling, and it may not make any

difference for the plot comparisons, but I find it unsettling because we know climate will not be constant over the next 160 years. Third, we all know that when you take trees off a landscape (logged, "managed"), topsoil is the first thing to erode, and it erodes fast. So holding C storage in the soil constant doesn't sit all that well with me either. How is this model calibrated??

- P. 25, ln 558. Habitat retention is another co-benefit of not logging forests.

Tables:

- Table 1: I can't really read this one.
- Table 2: If you are going to split a table between pages, maybe provide the column headings on the second page 2
- Table 5: Perhaps consider centering the MSE, F and p-values so they align with the headings.
- Table 6: Same as table 2.

Figures:

- Figure 1: I like this. Will look good when made in GIS.
- Figure 4: This one is a little difficult to read. Can you export it at a higher resolution, or trace it in illustrator?

Meredith Clayton
25 February, 2009
GEOL 371

Forest Carbon Storage in Northeaster United States: Effects of Harvesting Frequency and Intensity Including Wood Products

Jared S. Nunnery and William S. Keeton

This manuscript presents the results of a study conducted in order to assess the impacts of harvesting frequency and degree of post-harvest structural retention on Carbon storage in northern hardwood-conifer forests, as well as the significance of including wood products in carbon accounting at the stand scale. A secondary goal of this study was to find a method that could be applied to forests in other regions beyond New England. This was successful through the use of Forest Inventory and Analysis which utilizes widely available data, and through the use of the accessible USDA Forest Vegetation Simulator. The study used a series of simulated treatments that represented a gradient of increasing structural retention and decreasing harvesting frequencies, including a "no harvest" scenario. These simulations incorporated carbon flux between aboveground biomass and harvested wood products. These included carbon found in dead and live pools, as well as carbon storage in landfills. Differences among each of the scenarios were evaluated through the use of two-way ANOVA and factorial treatment design. The predictive strength for each management scenario was also evaluated, relative to site-specific variables using Classification and Regression Trees. The results of these simulations revealed the greatest amount of C sequestration is in "no management" forests. Similarly, active treatments that favor high levels of structural retention and lower levels of harvesting frequency sequester the greatest amounts of carbon.

My first reaction to this paper is to tell you to take a very long and well-deserved vacation! This paper is enormous. Your bibliography alone speaks volumes about the amount of time and energy you have put into this research. On a more serious note, I think you have been successful in interpreting large amounts of data and statistical analyses associated with this project, but I believe that some restructuring could potentially change this paper from impressively large, to powerful and concise. Upon reading this piece, I found it difficult to follow along with each subheading through the various sections. The employment of the subheadings is extremely useful for breaking up such a complex paper but because of the amount of information presented in each one, in addition to the larger sections, it is difficult to remember what you stated about a particular aspect in its corresponding subsection in a previous larger section. Perhaps this is most notable throughout the results and discussion sections. Typically I would advocate the separation of these sections given the sheer size of what you are attempting to summarize; however, I think that combining these sections could significantly improve clarity and eliminate some of the redundancy. I would propose incorporating the subheadings you have already used when organizing the results/discussion section. An alternative may also include subsections that divide your results/discussion between even versus uneven-aged silvicultural management scenarios. In addition to the proposed structural changes, I would also recommend some adjustments to the tables and figures referenced throughout the text. Aside from the changes that you have already indicated the need for, you should work to fit your tables to single pages, most notably Table 2.

You have also duplicated your CART analysis results table as Table 4 and Table 6. You will need to cross check all places in the paper where you have referenced this table to ensure that you are using a consistent reference number. This table should also have single spacing in its title rather that the double spacing currently presented with it. I have also noted that the use of italics to indicate significant p-values in Tables 5 and 6 may need to be modified. They are somewhat difficult to identify. Please see additional suggestions for the figures and tables in the mark-up.

Overall, I think that this is a well-written paper that has potential for some significant improvements. I would recommend its publication following some of the aforementioned changes, namely some restructuring to improve clarity due to the current size of the manuscript.

- Restructure to eliminate redundancy and to improve clarity
- Consider combining results and discussion sections utilizing subheadings to break up this large proposed section
- Clean up tables and figures (note there are many suggested edits in the mark-up that are not mentioned in this summary)
- Think of ways to consolidate this piece if possible.

Mark Isselhardt

Critical Writing (Geology 371)

2/25/09

Nunery, J. and Keeton W., 2009. Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products **for submission to Ecological Applications**

The authors utilize computer generated models to estimate carbon (C) storage rates in forests across northern sections of New York, Vermont, New Hampshire and Maine. The amount and rate of C storage for a period of 160 years was simulated for nine active forest management activities and a no cut control. The output of these simulations suggests that the no management alternative resulted in significantly greater amounts of carbon sequestration then any of the active management scenarios.

This manuscript is organized clearly and begins with a well rounded abstract. The abstract and title should probably state more clearly that the project is going to concentrate on above ground carbon storage. The introduction brings the reader into the ongoing debate regarding to extent carbon storage in forests and what impacts active management may have. There was clearly a lot of literature reviewed for this paper. The various citations help to stitch together the current state of the research but could do more to tie these papers to the study area. There is a concise and clearly stated definition for carbon sequestration/storage but it seems buried in the introduction (this is such an important part of the story that it needs to be front and center. The introduction repeats the research question and hypothesis twice and should be consolidated into one statement. The methods section did a nice job of explaining the computer model and how it was incorporated into the project. There is no real mention on soil nutrition and how it might affect the results. Could this be included in the introduction or methods? The data analysis section does a good job outlining the tests used but there are a few minor questions that remain unanswered; (on the tests for significance did you divide the alpha of 0.05 by the nine treatments?) The results section clearly showed that there was significantly higher C storage in the no cut scenario, were there significant differences between any of the other management scenarios? The sensitivity analysis section was a bit confusing. The CART analysis section could use a bit of strengthening. This section starts to get at the differences in management scenarios relative to C storage but the discussion section needs some sort of final statement on how the various methods differ. The discussion section starts off with a clear statement that “management intensity strongly affects C sequestration…” But it is hard to tell from the results if there were clear levels of harvesting intensity that resulted in significantly different levels of C storage. The discussion section covers a lot of ground and could stand to be focused a bit more on the current projects results and their implications.

This paper deserves to be published with minor revisions. There is a list of small items for the authors’ consideration at the end of this review. If there is one single area to be worked on prior to submission of this manuscript it would be to concentrate on the core issues being tested and their immediate relevance to the Journals readers.

- L61 A simple illustration that diagrams the important physical parts of the forest carbon story would be great to have in the introduction. This diagram would not have to have lots of numbers but it would be something to give the subsequent research some visual context (trunks, branches, leaves, soil and roots). This illustration could give rough estimates of the total carbon on site (even the carbon not accounted for in this research).
- L175 What is meant by "well-distributed" sample? Do you mean in terms of geographic or ecological attributes? What were the criteria used to stratify the samples? Was there a selected proportion of each site?
- L251 What is the reader to do with the information presented in Table 3?
- L321 What is the new Bonferoni adjusted alpha value? Did you use this value in your subsequent tests?
- L420-423 These concepts have been addressed previously.
- L520 The "Model Assumptions" section should probably go in the methods section.
- Table 1 was hard to review
- Table 2 this information is helpful but is would be nice to include a line that shows the ranges and means for each component.
- Table 3 This information seems a bit extraneous.
- Table 5 What is the alpha level selected for significance?
- Table 6 As mentioned above, the sensitivity analysis section was a bit confusing.
- Table 7 (was labeled table 6) is the same as Table 4
- Table 8 This able is a bit thin on title information. What is n for this analysis? It would be good to include what the various harvesting cycle lengths were.
- Figure 1 This map includes a lot of information. Consider a more basic map and remove the elevation relief, and labels for individual section codes.
- Figure 3 This is where the reader turns to see if differences exist between treatments. It would be nice to include the results of ANOVA with this graph.
- Figure 4 The CART output does not lend itself to easy interpretation. The caption helps some but it would be nice to have more explanation in the body of the paper.

Interesting project Jared, good luck with publication.

Review of: Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products

Authors: Jared S. Nunery and William S. Keeton

This paper shows the effects on carbon sequestration due to varying levels of forestry management, using models and data from tree stands in the Northeastern US. The introduction of the paper discusses the state of carbon sequestration on an international and national scale; the relevance of better understanding the effects on C sequestration due to management practices is introduced. The complexity of carbon pool fluxes is brought up, and it is explained that the effects due to harvesting frequency, intensity, and storage in wood products and dead trees will be considered in the model. Forest stands in Northeastern US are used as inputs for the model. The established forestry model uses inputs from basal area, tree regeneration, and species type. Nine model scenarios are looked at over a 160 year model time period: one scenario is an unmanaged forest, the other 8 scenarios are variations that combine different harvest intensities, frequencies, and whether the harvests are even or uneven aged. Statistical tests (1-way and 2-way ANOVA) are performed on the mean C sequestration from each scenario over the 160 year period. Figure 2 illustrates the C sequestration over time, and what kind of interactions are occurring due to different management practices. Overall it was found that management that includes high levels of structural retention and low harvest frequencies will have the greatest C sequestration. Both, harvest frequency and post-harvest storage are considered important for C storage.

This paper does a very impressive job of showing what theoretically happens to C with 9 distinctly different silvicultural management scenarios. The fluxes of C pools seem complex, and you do a good job of pointing out where C is going, but I think a process flow diagram would be a huge help in conceptualizing C pools and fluxes. This paper does a good job of addressing possible modeling flaws, and addressing them. The CART analysis is used to account for affects on C uptake rates, this is probably good, but I do not completely understand what that means. Another modeling consideration is checking the sensitivity of C uptake rates, pertaining to regeneration inputs. For the ANOVA where the different management treatments are compared (C sequestration uptake means for the entire 160 years, n=16) I was wondering if you should mention how there is some dependence in the values that are used to obtain the mean (independence is an ANOVA assumption). Also, from figure 2 it is apparent that the mean in the beginning of the treatment for some scenarios may be different to the mean at the end of the treatment for the same scenario, and considering this change may show some other interesting trends that can be discussed. Since you are dealing with modeling data I think it would be valuable to include percent error that is associated with outputs. This paper has a lot going on and I am a novice in this field, so it is hard for me to be to critical. I hope my comments in the text will help you understand where I was not completely clear about what you were discussing.

After some revision I think this paper should be accepted because it will be an important asset to the scientific literature as well as to forest and environmental managers. This

paper has broad implications, and I think you should make sure this comes through clearly before you submit to this particular journal. Following are some additional comments I have (you can find more comments in the printed PDF):

- In the intro (page 7) you mention other models used, are there papers that discuss outputs from these models? I thought it would be interesting to know what these models were used for. You say you will use the FVS model, have there been other studies done with this model?
- On page 10 you introduce the different harvesting intervals, and this was not completely clear. Does table 1 address these times?

Overall the paper shows a very detailed study with pertinent results. Good luck with the editing.

Martin

Paper: 'Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products' by Jared S. Nunery

Reviewer: Nikos Fytilis – 02/25/09

This document describes the impact of harvesting frequency and degree of post-harvest structural retention on carbon storage in northern hardwood-conifer. The authors used several different models and statistical methods to test the significance of including harvested wood products in combination with the above parameters. Even though the dynamics of storage and fluxes among different sinks impacted by management are complex, the nine scenarios used provide a clear overview of several cases for both managed and unmanaged forests. The focus of this paper is to examine the net effects on C dynamics across a range of silvicultural systems. The results of this research and the hypotheses could be used by land owners and forest managers to evaluate or construct a better forest management on C sequestration.

This manuscript is through and well written, providing clear detailed descriptions of the variety of methods and scenarios used. You have done a lot of work and I think you presented with the best possible way. This paper includes specific scientific language but the main terms were explained perfectly. The readers of this document could access a large amount of information in a very well organized structure. The abstract contains large number of terms and abbreviations which will not help the readers who are not very familiar with the subject. In the introduction, I believe you did great job describing the general status of forest management and C storage and using relevant studies to illustrate what gaps your research is going to fill in. The only part I found difficult to follow was the very long paragraph on page 5-6 because I think that the last sentences and the information presented are not needed. One other thing that it could make your introduction shorter is to move some information to other parts of your paper (e.g. the last part of the first paragraph on page 7 could be moved to model description). Also in the last sentence of your introduction, you mention nine scenarios but in Table 1 are only eight so it is better to use instead the first sentence in the silvicultural simulations.

The methods and the study area are well presented. I hope that Figure 1 would be better using GIS. In model description part I couldn't understand how you select some numbers (e.g. projection years, harvesting intervals). In line 243 you mention that you want to capture a minimum of one complete rotation length. What exactly is one complete rotation length and why it is important for your research? Maybe you should explain more the statistical methods you used especially the post-hoc Bonferroni multiple comparisons. If I measured correct you presented nine scenarios, you did sensitivity analysis for them and you had two hypotheses to test. I want to point out that you did a fairly good job but you could re-write this section so it would be more clear the different scenarios and sensitivity cases. On page 17 you mention that only four variables were incorporated in the final CART model but you don't mention which four of the total eleven. You back up your work and hypotheses with the results from the different statistical methods. I would like to see a clear section of proposed future steps and a different conclusion because at some points you just restate your results. Finally, the section of the model assumptions I think it should be between the methods and the data analysis and

Overall, I think it is a great paper with a lot of work done and should be published with some revisions.

Good luck.

Review of

Forest carbon storage in the northeastern United States: effects of harvesting frequency and intensity including wood products

Jared S. Nunery

This paper looks at carbon sequestration in hard wood forest in the the northeast US. The purpose is to determine if unmanaged forests sequester more carbon then managed forests. The thought is that managed forest grow faster and trees removed to be turned into lumber or other products that sequester the carbon long term. This project is important because it allows us to understand if is better to manage a forest or let it grow on its own for sequestering carbon and selling carbon credits. The project discovered that forest sequester more carbon the less they are managed.

This paper, from what I can tell, has data that is of high quality and reproducible. The interpretations make sense but I think there need to be more work looking at properly managed hard wood forests and their potential for sequestration. For the most part the writing is very clear, but occasionally sections are poorly explained and hard to follow. The figure are good, the last one is a little hard to read and the captions I think need to contain more detail.

I believe this paper should be accepted with revisions. The paper should be accepted because it adds a much better understanding to forests and their sequestration of carbon. This currently is a be topic but will become much large if the national government starts a carbon credit system. There are a few things that could be improved though.

1. For me it would be easier to read is C was replace with “carbon”.
2. Some portions of the paper need to be better explained to be accessible to all audiences.
3. I think this paper is running the danger of being to long. This length may be the norm for the journal you are publishing in, but for me personally I felt it was a little long.

The paper seems to be compliant with all the rules, as far as I can tell.

Charles Trodick

Review of: Forest Carbon Storage in the Northeastern United States of Harvesting Freuency and Intensity Including Wood Products

By: Nunnery and Keeton

Jared,

I thought this paper is quite good in its current form. It is well constructed in a logical fashion that does a good job of reporting your results through the methods, which are also fairly well described. This paper begins with a general overview of forest processes in terms of carbon storage and management. The dual hypotheses of the paper are then spelled out, the first being that even when wood products are factored into the mix unmanaged forests (ie; old growth) sequester more carbon than any forest management scheme. The secondary hypothesis is that less intense use/management of managed forests would provide greater sequestration than any other management approach. The results found that these hypotheses ring true and leaving well enough alone really would be the most ideal scenario.

Overall I felt that, despite not being part of this field, I had a pretty good understanding of what I had read. There are however, some additions that I think would strengthen the work as a whole. Firstly, the introduction did not seem as clear as it could be. I found that prior to reaching the hypothesis section- which is excellent and very clear- the flow did not seem clear enough. Also in the introduction, the addition of some more justification could really ground this research and make it more widely applicable. Another smaller note is that there are some points in the introduction that could potentially be moved to the methods section, thereby making more space for the additional justification information.

The methods section was quite helpful, I thought that the wide array of sub-headings was key to the overall effectiveness given the complex descriptions of models and etc.

The results section was descriptive and clear. I think this paper may be able to benefit from combining the results and discussion. While this will make for a lengthy section, your use of subheadings will allow this to flow better as a combined section, thereby making your results and their importance more explicit. Moving into the conclusions, these could be improved upon by tying your results back into wider implications both in our region and in other places. Another point that might be helpful is a very concise statement of your results before jumping into the implications of these.

With these changes I suspect that this paper will become stronger and will bring important results to the forest community through publication. Good Luck finishing it up,

Will