Review Response: Trees in many US cities may indirectly increase atmospheric carbon

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Summary of Changes

Response to Reviewer Comments

Referee: 1

Review report ERC-100072.pdf

Comments:

1. The results of yours are so strongly dependent on the number of heating and cooling degree days and the fuels/technologies utilized for electricity and heat production, that it does not make sense presenting the results without this information presented first.

   (a) I mention this in the 4th paragraph on page 3, lines 44-45. I will add emphasis to this point at the start of the discussion section.

2. You should not satisfy with your case results, but look at the conditions in which the balance is turned other way round (referring to the first comment).

(a) This is what I attempted to do by updating Akbari and Konopacki 2005 model. I think that a proper analysis that could accurately identify the thresholds in climate and other important factors where the effect of trees is reversed is beyond the scope of this paper. My aim was to present our case results and show them in the context of past work that I think was ignored.

3. You should discuss the distance issue in the introduction. Now you are sort of partially discussing all urban trees, but then continuously referring to "shade trees". You also refer to energy need reduction as the primary gain from tree planting programs, which points at these shade trees rather than all urban trees.

   (a) I will add text in the 3rd paragraph to this effect.

4. You go deep into the previous studies in the introduction. I suggest splitting up the section to a shorter and simpler introduction and previous literature gap analysis.

   (a) Good idea. Thanks.

5. Don't limit your generalizability discussion to just the U.S.

   (a) Thanks for the suggestion. I'll change "cool climate communities in the US" to "cool climate communities". For the part of my work that builds on Akbari and Konopacki 2005, I will keep the US centric view.

6. I wonder why you don't mention building types at all in the introduction. It is not uniform how the shading effect works with buildings of different types, and presumably in cool climates the buildings are on average better insulated.

   (a) This is very true. I mention "building characteristics" in the 4th paragraph, but will expand on this. It it certainly true that as buildings become better insulated the effect of trees on their energy use decreases.

7. Extend the study description from the current one short sentence on lines 107-108. Even if the paper follows the style guideline placing the methods and data descriptions to the end, you must briefly tell to the reader what was done.

   (a) Thanks for the suggestion, I will add text there.

8. Please explain better how only north side cover can lead to an increase in the need for warming. Shouldn't tree coverage lead to lower heat loss through the north wall?

   (a) I agree, this result is highly suspect and I'm honestly not sure why the coefficient is positive. Please see the additional paragraph in Discussion > Interpreting Tree Effects.

9. Extend the C storage comparison section with the actual outcome numbers and meaning.

   (a) I'm sorry I don't know what you mean here. I thought that a green ash with crown area of 100m^2 would give readers a sense of the numbers. What other numbers should I provide?

10. In the "considering the larger C cycle", I would find it appropriate to notice that hundreds of years of storage can be very important in mitigating climate change now and allowing for energy system transition to take place.

    (a) That may be, and I will add text to that effect, however this would mean short term reduction in atmospheric C and long term elevation. If energy system transition doesn't occur, we'll be worse off than without trees (with regard to atmospheric C). Though it's not that big a deal either way since the relative effect of urban trees is small.

11. You are making several assumptions yourselves, but don't discuss much this aspect of your study (you point out some weak assumptions in previous studies).

(a) Do you have any specific critiques of my assumptions? I don't think other studies assumptions are weak. For example, results in cool climates are highly sensitive to how wind is modelled. The effect of trees on wind around buildings is a highly complex relationship (and therefore very difficult to get right), but existing models all depend (as far as I know) on just 4 data points from one place over a short time period with low wind events removed. This creates huge uncertainty. Are you aware of sensitivity studies that assess how important various assumptions are in these studies?

Referee: 2

COMMENTS TO THE AUTHOR(S)

- The paper summarizes the results of a statistical analysis.
- No data or results are shown and the reader has to rely on the authors for their conclusions.
  - I provided data and all the code for the analysis in a github repository.
- The physics of the claim that trees increase CO2 emission is not explained and modeled.
  - Please see the introduction, especially the third paragraph. How trees can affect energy use of buildings is well covered in many of the papers that I cite. I provide a short explanations and the citations for readers. The linear model I use is simple but a clear empirical demonstration of the link between greater tree cover and greater C emissions for residential buildings in Madison. My aim is not to model the physics of the relationship, but to provide an empirical demonstration of the link between tree cover and building energy use and the associated C emissions. I use my results to question the validity of the commonly cited ecosystem service that trees reduce ACE even in cool climates.

- One cannot understand the basis of the conclusions with supporting data.

  - Do you have suggestions for how I can be more clear? Is there a part of the text that is confusing or do you have a suggestion for an additional section of text that would help make things more clear?

Referee: 3

COMMENTS TO THE AUTHOR(S) [See also $ER_{systemappendPDFproofhi.pdf}$] Nice paper. Comments are on the attachment. The paper needs some clarification of methods and a little more discussion, but overall it is a very good paper. My main issues relate to using the Akbari and Konopacki results to extrapolate to the nation; how you were able to separate shade and wind effects; and the discussion should delve more into why these patterns occurred.

One item you might want to expand on in the discussion is that though your results contradict most, but not all, results for northern climates, they do not necessarily negate the findings of past studies. It opens an interesting question for more research though. You basically have an analysis of one city (the national analysis is questionable). Other studies used energy simulations that had limitations, but your results do not necessarily render previous studies as incorrect. Past studies have found these negative winter effects, but maybe not to your degree. Your work is interesting and opens questions for further research, but is not conclusive nationally. Your work compares one modeling approach results with other modeling approach results; and both have limitations. Bottom line is that trees in more northern climates could increase carbon emissions and more research is needed as to how much and why.

- Thanks for your comments. I think you have summarized the main point of my work well, and I will try to incorporate all your suggestions. Do you have citations for the other studies that have found trees are associated with an increase in building energy use and C emissions (or are they just increased energy use in winter)?

Comments on pdf (lines are from original submission):

- Title. Maybe add "due to altered energy use" in the title as your findings indicate that if sequestration is included, carbon has a net positive sequestration.
  - see edits to title
- I like this analysis, but have issues with these types of analyses as they are basically correlations of data. The big questions is what is the cause of the results? There is no cause and effects shown, just a relationship. Past studies (McPherson, Akbari, etc) have shown winter time increases in energy use due to trees as you also show, but why are there increases in electricity use due to trees in the east and far west? Also why do tree to the north increase gas usage? The why is the most important question. I see you address the east question later, but why the north finding?
  - This is unfortunately the nature of an observational study, but there is still great value is having actual data.
  - I try pretty hard in the text to make sure I only talk about associations/correlations between tree cover and ACE, because I can't possibly demonstrate causation with the study design. Given what we know about trees, I think it's likely there is some causation. But there is no way to experimentally manipulate a city to determine causation. And, as I mention in the text, simulation studies are foundational to our understanding but they are wrong (all models are). We don't know how wrong they are until we assess them with empirical data. This has never been done before.
  - You say that McPherson and Akbari show winter time increases in energy use due to trees. As far as I can tell (please correct me if I'm wrong), McPherson always shows that the wind reduction from trees in winter reduces gas use far more than shading increases it.
  - All that said, your point is a good one. Our study is certainly not a perfect validation of the simulation studies and I agree that some of the coefficents do not have an obvious

explanation given our current understanding and they may very well be wrong. My hope is that with a different type of study we can move closer to the truth and put more emphasis on how this is a complex relationship and the ulimate direction of the effect is context dependent.

- line 126. This difference also has to do with the ratio of emission to the fuel source. If one changes the fuel, the C emissions will change but the energy effect will stay the same.
  - Yes, I mention this in other places of the text.
- line 142. "So the tree is a net reduction in C? Maybe report the net effect of both to be clear"
  - I was hesitant to discuss net C because the C is being moved from different pools. While C in atmosphere is decreasing in the short term, C in the atmosphere-biosphere system is increasing. That said, I will add text to make it clear that sequestration is greater.
- line 147. "How do you know shading was the driving factor, vs transpiration or wind? Also how does comparing winter vs summer effects lead to the conclusion for winter effects?"
  - Determining the role of wind, shade, and evapotranspiration is not possible with my data, but I attempted to interpret my results in light of past work. I used the word "suggests" because I do not know the cause, but am building on what others have suggested the mechanisms are. I need to be more precise with my language to indicate this and will add additional text to clarify. Please let me know if I have not adequately addressed this issue
- line 153. "Good"

- line 161. "Why might this be?"

- line 178. "Although I agree with this conclusion, I find it somewhat contradictory that the basis for this work in the introduction is the limitations of past studies, but you use these past studies to extrapolate nationwide. Why not just use your findings to make this point - in heating dominated areas, tree can increase C carbon emissions. Extrapolating the Akbari data is suspect due to their assumptions on tree cover. Your data are from actual tree distributions. I would drop this national analysis as it is already known that trees can increase winter energy use. Use past studies to back your findings. Also note that fuel mix is important in carbon emissions as is tree location."

  - I hope that the rewriting of the text clarifies many of the issues you raise in this comment. I agree the akbari method has limitations, but even with them I think it is useful to show that past simulations predict trees increase ACE (under their assumptions). I don't think it is commonly known that trees can increase annual C emissions. Pataki et al. (2006) and Weissert et al. (2014) don't mention it. The fact that there are some negative shading effects is known, but studies always seem to show them compensated for by wind reduction or savings during the summer.

- line 184. "McPherson and Simpson methods are used in iTree, but it is not the model."

  - Could you please clarify this more? When I emailed the folks at iTree I was pointed to McPherson and Simpson. Do you know of important ways in which they differ? I adjusted text so that it doesn't look like they own it.

- line 185. "Northern"

  - Thanks for the catch.

- line 188. "How did you separate out shade effects?"

  - I did not, but our work agrees with the shade effects proposed by other studies (that trees increase gas use for heating) not the wind effects (that trees reduce gas use for heating).

- line 192. "I am confused as to how you can separate or did separate wind from shading effects"
  - see above and added text that seeks to clarify this confusion.

- line 218. "It might good to note that this information can also be used to improve planting designs, particularly in colder climates to reduce energy use and carbon emissions"
  - I will put this in future work and the conclusions.

- line 235. "Good"
  - thanks

- line 267. "Again, I do not see how you conclude this difference between wind and shade."
  - I hope my clarifications above and in the text helped. Please let me know if I need to do more. Changed text here to "may be due to" rather than "is due to". Apologies for undue certainty.

- line 309. "What is the accuracy of the tree cover data?"
  - added

- line 327. "What is the accuracy of the building cover data?"
  - added

- line 374. "This is confusing text as to what was actually done. Are you interpolating Akbari and Konopacki results to this area with 77% of the population? If so, how to do you account for varying tree cover across the nation? The Akbari paper uses 4, 8 and 10 trees around the building for their assumption of tree cover. If you are arguing that these previous models have limitations based on their assumptions, why use these models for national extrapolation. I may be misreading these methods, but either way, these methods needs to be clarified."
  - I will work to make this more clear.
  - Determining that 77% of the population lives in an area with more heating degree days than cooling degree days is a separate analysis that just depending on finding the climate at each census tract. It was the prerequisite to applying akbari and konopacki's model.
  - My primary aim of mapping the work by akbari and konopacki was to show that while there work from 2002 "Shade trees reduce building energy use and CO_2 emissions from power plants" is true on average, the headline does not apply to much of the country and their own work shows this.
  - In this context I think it's possible to build on their work (despite all the limitations I mention) to show that there likely are places where trees increase ACE. Where those places are exactly is unknown, but our work provides strong evidence that Madison is one of them.

Letter reference: DSMa01