Response to Reviewer #1:

Overall, this is a well-written paper that succinctly describes the methodology for this new geospatially-distributed crop carbon data product for the United States, as well as associated efforts to balance the crop carbon budget for this region. The geospatiallydistributed data product will be especially useful for constructing total source and sink maps for the United States in other carbon budgeting studies. My suggestions here are intended to make the paper easier to follow and more interesting in terms of the interpretation of the results.

One general caveat is that it's hard to know which of the datasets used in the crop carbon budget shown here were created for this paper, and which were previously published. I would try to make this clearer throughout the paper.

Thank you for the suggestion. The methodology for the inventory-based NPP estimates was previously described and used by West et al. (2010), the human carbon stocks and fluxes were previously described and used by West et al. (2009), and the soil carbon method was previously described and used by West et al. (2008). Methods used for estimating livestock emissions are described here for the first time, and data were generated using this method for the first time in this analysis and paper. Additionally, this is the first time that all of these components have been brought together to estimate geospatial net fluxes of crop-derived carbon, and to complete a national crop carbon budget for the US. We have clarified this, as suggested, at the end of the first paragraph in section 2.

The geospatially-distributed net crop carbon exchange figures (Fig. 4, (g) & (h)) and discussion are interesting, although it might be nice to have a sense of the magnitude of these fluxes in the context of total carbon flux to & from the atmosphere. Perhaps a map of percent area in agricultural production would help the reader to get a sense of where agricultural fluxes are likely to be the dominant component in the total carbon budget.

We agree that discussing the agricultural fluxes in context with forest carbon fluxes and fossil fuel carbon fluxes would be useful. We are currently working on an analysis that includes all sources and sinks. As suggested by this reviewer, we have included an estimate of total US CO_2 emissions and a comparison of this total to that taken up by crops each year (Page 13, lines 252-256). We anticipate a separate paper in the near future that brings together agricultural, forest, and fossil fuel fluxes, and that discusses the relative contribution of each component to the total carbon flux.

With respect to a map of agricultural production, we believe that Figure 4(a) illustrates the geographic pattern of cropland carbon well. Figure 4(a) represents the harvested and removed carbon fraction. However, the crop NPP map looks very similar, but with much higher numerical values. Figure 4(g) (now Figure 4(d)) illustrates the net carbon uptake and release of crop-derived carbon, thereby providing a map of where agricultural-related carbon fluxes (i.e., uptake and release) are expected to occur.

We note here that we removed the original Figures 4b,d,f,h. These component maps of Figure 4 illustrated the carbon flux on a per ha basis. However, the contribution of these maps to the overall message were little; they took up space; and they required us to make the maps smaller and more difficult to read. Additionally, putting crop carbon fluxes on a per ha basis makes sense, but putting livestock emissions on a per ha basis is not logical, due to the variability of land area used for livestock populations (e.g., grazing vs. feedlot). We therefore, restricted our illustrations to total carbon flux per county in the U.S. and enlarged the remaining maps.

I would like to see more interpretation of the trends found in the US crop carbon budget from 2000 to 2008. Are there other points to highlight beyond the increase in use of corn for ethanol (and the corresponding reduction in livestock feed, carryover, etc.)?

The primary purpose of the paper was to quantify the US crop carbon budget, to analyze the fluxes spatially, and to provide the methodology behind the now publicly available data. We analyzed the fluxes according to USDA ERS Farm Resource Regions. The additional findings regarding correlations in biofuel use, livestock feed, and carryover reserves were an unexpected result of our analysis, but one worth mentioning.

Some example points for discussion of the crop carbon budget are as follows: it looks like human food consumption has been growing over this 9-year period, but crop carbon for livestock feed has been declining. Given increasing meat consumption, does this mean that there are more grass-fed cows or is more of this meat imported? Also, there appears to be an increase in both imports and exports of agricultural products. What is driving this? (Who are the major trading partners?) Why did the amount of harvested cotton decline from 2005 to 2007 (p. 640, lines 14-15), and then go up again in 2008? How much of the change in crop NPP over this period is due to weather vs. management practices and land use? What drives the amount in carryover from year to year? Is this purely market-driven, or are there laws requiring a certain amount of crop production to be held in reserve? For example, 2004 had the smallest amount held in carryover, despite the highest harvest over the period. What drove that outcome? It may be that the answers to the previous questions are common knowledge, or previouslypublished, but I think that more interpretation of the numbers within the crop carbon budget over this nine year period would make the paper more interesting to read.

These are very important questions, although they require some research on social and economic drivers of agricultural production. In fact, our carbon estimates can be used with social or qualitative information to drive economic forecasting models of agricultural production and subsequent carbon flux. Unfortunately, while this is possible and needed, the analysis of social and economic drivers and their influence on agricultural production and carbon dynamics is outside the scope of this analysis and paper.

In a recent paper that investigated emissions associated with agricultural production inputs (Nelson et al. 2009), we discussed the main influences on crop production. As you alluded to in your question, annual weather has a large influence on short-term annual changes in production. Longer-term annual changes are driven by the commodity market. To highlight the importance of these questions you have raised, we included a citation to the Nelson et al. paper and discussed some of the factors that influence crop production and associated regional carbon fluxes (page 31, lines 251-252).

Overall, the crop carbon budget is remarkably balanced given the complexity associated with tracking all flows of agricultural carbon within the United States. However, it looks like the imbalance is consistently in one direction, except for 2008, (i.e. not all of the fixed carbon in NPP has been accounted for in terms of subsequent releases back to the atmosphere.) Maybe you could speculate on where you think this "missing carbon" may be within the different categories of the budget? Even without firm evidence, it would be nice to see more interpretation in this area.

Yes, it is remarkably balanced, particularly since many components of the budget come from independent datasets and empirical models. You are also correct that it is consistently biased in one direction. It consistently shows that we have not accounted for a small portion of the ultimate use and release of carbon. The percentage of this error is quite small (0-6% per year). We have no firm evidence for the small bias, nor are we able to speculate at this time what the cause(s) may be.

It was somewhat confusing to me when livestock consumption included just crop carbon, and when it included both crop carbon and pasture. Specifically, the paragraph starting with "The county level flux estimates in our analysis. . ." on page 638 was confusing. You state that "Consumption of crop carbon and pasture carbon cannot be differentiated by livestock population and county." But then, the following statement says "However, we excluded non-crop carbon (i.e. pasture grazing) from the national crop carbon budget." How were you able to do this at the national scale, but not at the county scale? Also, it looks like you did not disaggregate pasture grazing from livestock emissions in Table 4 at the scale of US Farm Resource Regions. Why not?

We have added text to the manuscript to further explain this. We will also clarify it here. We estimate livestock emissions at the county level according to species and total consumption, not by the type of food consumed. Therefore, we cannot separate livestock grain feed from pasture grazing within the livestock diet at the county scale. We are also interested in balancing the cropland carbon budget in order to ensure that our datasets are accounting for the majority of crop-derived carbon. Unlike data at the county level, we are able to separate crop feed grains at the national level. Therefore, we can use these estimates of crop feed grains as an independent component of our annual crop carbon budget at the national scale to assess the ultimate use of all crop carbon, and thus derive the livestock respiration associated with crop commodities compared to pasture carbon.

It is important to realize that pasture/grass is NOT considered a crop commodity in the USDA NASS data, therefore it is not included in the total carbon uptake (i.e. crop NPP estimates). One thing we have to keep in mind here is that before recently there was no reason to track carbon vertically or horizontally. We have both science and policy reasons to do so now. As this is a new and evolving area of research, we have to use currently available data that were often collected for different purposes and that aren't necessarily consistent in their data collection methods. What we are providing here is a best estimate of the current crop carbon budget and what it looks like spatially.

Also, I think that the previously mentioned paragraph on page 638 was the first mention in the paper of using slightly different methodology for the national budget vs. the geospatially-distributed dataset. I think that a clearer up-front mention of these two final data products (before discussing individual components, maybe in Section 2 before 2.1) would be warranted. The final statement on page 634, line 25 says that the estimates are at the annual, county scale. I would also mention the national crop carbon budget here, and why you used slightly different methodology at this aggregated scale.

Yes, we agree that this should be explained early in the methods section to avoid confusion by the reader. We have clarified this in the second paragraph of section 2. The carbon budget is at the national scale and its purpose is to attempt to account for the production and use of all crop carbon, thereby completing the crop carbon budget. The county scale analysis is to illustrate the datasets, the spatial

pattern of carbon fluxes, and to provide the spatial unit for analyzing what is predominantly county-level statistical data.

Page 639, first sentence in Results: I would add a caveat to this sentence stating that this crop carbon data product will be useful for comparing to atmospheric measurements only after accounting for other non-agricultural CO2 fluxes, both biospheric and anthropogenic, particularly in areas with mixed land-use.

We did not intend to imply that only crop fluxes are needed for comparison. As suggested by the reviewer, we have clarified this at the end of the first paragraph in section 1 by stating the need for all emissions sinks and sources. This paper focuses only on crop carbon in an effort to improve quantification of this component flux. We note here that, in some cases, inverse models are separating out fluxes from agricultural areas and conducting direct comparisons with inventory-based estimates. Such comparisons will be published in the near future.

Would it make sense to post this geospatially-distributed dataset in a publicly available ftp site, and make mention of it in the paper? Regardless, I think you should include a statement regarding how to access this data for interested scientists.
Figure 4 is very small and hard to see. Do you need to show both the county-level and per unit area maps? I might choose one or the other. Also, maybe you could put the figures in the first 3 rows on a common scale, so you would only have to show one legend per column? I could also see putting the fourth row (net crop carbon exchange) into its own figure given the scale difference.

Yes, indeed. The data have been posted to http://cdiac.ornl.gov/carbonmanagement/. This is noted in the captions of Tables 1 and 2. We have also added a statement and link in the Acknowledgments. Data are distributed with associated county FIPS codes which enable the data to be joined to county-scale maps in any GIS software. These datasets will be updated as we generate improved versions.

Yes, we agree that the figure was small. We deleted the per unit area maps, as you suggested, and made the remaining maps larger. We are concerned with putting the maps on the same scale, because it would be difficult to see the spatial pattern in some of the maps (i.e., human consumption map).

Final note:

We would like to thank referee #1 for insightful comments that have improved this manuscript. Some of the questions posed by this referee merit additional attention and, while outside the scope of this paper, could potentially be addressed in a future publication.

Minor changes in the estimates of crop NPP have been made since the previous addition. Changes consist of a more robust gap-filling method using district level data to augment the county level crop data. This change has resulted in small changes in crop NPP and harvested biomass. These changes can be seen in Tables 3 and 4 and in Figures 1 and 2 when comparing the final paper with the paper submitted for initial review. These changes do not influence overall trends or patterns in the carbon fluxes or the conclusions of the paper.