Responses to authors
Revised mmanuscript entitled:

Modeling Land Use and Land Cover Change: Using a Hindcast to Estimate Economic Parameters in gcamland v2.0

Geoscientific Model Development

Anonymous

In what follows I responds to the authors using green fonts

Anonymous Referee #2

Summary of the paper This paper uses gcamland/GCAM to calibrate/estimate/tune the land distribution parameters of a nested logit land allocation function used in this model. In the lack of econometrically estimated values for these parameters, it is an important effort to accomplish this task. However, the paper suffers from some important deficiencies and lack of clarity, in particular for those who do not know this mode.

Author Response: Thank you for your detailed review of our paper. Your comments have pointed out a number of places where we did not clearly describe our methodology.

Author Changes: We have made a number of changes to the paper in response to your comments and those of another reviewer. Those changes are detailed below.

Response: Thanks for your attention. Your responses helped me to understand your work better. However, in some cases your responses were not convincing. In what follows I highlight my comments using green fonts after each response.

Some important comments:
1. I am not a GCAM modeler but is seems gcamland operates under GCAM. For nonGCAM community the links and interactions between these two models are not clear. How they linked and interact. A simple chart can help.

Author Response: GCAM and gcamland are completely separate models. GCAM includes representations of energy, water, land, and climate. It includes a land allocation mechanism where land use and land cover are calculated based on changes in profit. gcamland only includes this land allocation calculation. gcamland is not run when GCAM is run; GCAM is not run when gcamland is run. Instead, gcamland replicates the land allocation equations used in GCAM so that we can isolate that part of the code for analysis and uncertainty quantification. See also response to comment #19.

Author Changes: We have added a footnote to the methodology section clarifying the relationship between GCAM and gcamland: “GCAM and gcamland are separate models. While gcamland replicates the land allocation mechanism in GCAM, it is not run within GCAM. Similarly, GCAM is not run as a part of gcamland. gcamland only includes a representation of land allocation. GCAM includes representations of agricultural supply and demand, land allocation, and other sectors (energy, water, economy, climate). The land allocation mechanism within gcamland uses price, yield, cost, subsidy, logit exponents, expectation parameters, and initial land area as exogenous inputs and endogenously determines land area in subsequent years.

Changes in demand are explicitly represented in GCAM. In gcamland, changes in demand are captured through changes in price. For example, the increase in demand for corn and soybean due to biofuels policy is captured through changes in the prices of these goods."

Thanks, it seems the CGAM model plays no role in the estimation process of the estimated parameters and only the gcamland with no demand side has been used. If that is the case, then the paper needs revisions to make sure that CGAM has not been used in the estimation process. For example, here are a few places that need attention:

- Table 2, Description of Arable Land should refer to "gcamland" not "GCAM", as noted in footnote 5.
- Change title of 2.1.2 to "Economic approach in gcamland"
- Change title of section 2.3 to "Evaluation gcamland model performance"
- Change the end of line 204 to "… focused on annual time step in gcamland"

2. The model clearly uses a nesting logit format, perhaps three nests. Equation 1 of the paper shows only on nest. The formula should be replaced with a formula for the full nest.

Author Response: We have added information on how profit and shares are calculated for the other nests.

Author Changes: We have added additional text and an equation "In the three-level nest version, land allocation at each level is determined by a modified version of equation 1, where Y is replaced by the land allocated to that particular nest. The land allocated to a particular nest is dynamic and varies over time. Profit rates (r_j) at the lowest level of the nest are computed based on price, cost, yield, and subsidy (if included) for land use types (crops, pasture, commercial forest); profit rates for land cover types are input into the model and are based on the value of land. Profit rates for higher levels of the nest (r_{node}) are determined by: $r_{node} = [\sum_{j=1}^{n}(\lambda_j r_j)^{\rho}]^{1/\rho}$

The revision mentioned here is helpful, but it provides a broken formulation and misrepresent your work. To be fully transparent and to make sure that the readers understand that three exponent parameters (distribution parameters) and there sets of share parameters were estimated, I propose to use the following format:

$X_{jt}^{C} = \frac{(\lambda_{jo}^{c} r_{jt}^{c})^{\rho^{C}}}{\sum_j (\lambda_{jo}^{c} r_{jt}^{c})^{\rho^{C}}} \cdot Y_t^{C}$ where "C" represents the crop nest including rice, wheat, ……

$X_{jt}^{A} = \frac{(\lambda_{jo}^{A} r_{jt}^{A})^{\rho^{A}}}{\sum_j (\lambda_{jo}^{A} r_{jt}^{A})^{\rho^{A}}} \cdot Y_t^{A}$ where "A" represents the ag-forestry nest including cropland, forest, ….

$X_{jt}^{R} = \frac{(\lambda_{jo}^{R} r_{jt}^{R})^{\rho^{R}}}{\sum_i (\lambda_{jo}^{R} r_{jt}^{R})^{\rho^{R}}} \cdot Y_t^{R}$ where "R" represents the arable land nest including …..

The members of each nest should be clearly mentioned. In particular, for the crop nest all members of this nest including unused land, cropland pasture, CRP, other idled land should be specified. The information that presented in Table 2 is incomplete and very misleading. Of course, the names of variables should be described fully and maintain this convention through the paper.

3. How the land constraint/constraints is/are defined? Does a simple land constraint directly add all types of land: Total land =forest + pasture + corm + soy+ etc.? or each nest has its own land constraint?

Author Response: The only explicit constraint on land in the model is on total land. That is, we require the sum of all land types (forest, pasture, grassland, shrubland, urban, crops, etc.) to equal the total area in the United States. We parameterize the model to prevent expansion of cropland into non-arable lands (urban, tundra, and rock/ice/desert).

Author Changes: We have clarified this in section 2.1.2: "The land allocated to a particular nest is dynamic and varies over time."

Thanks for the clarifications that: 1) only one land constraint is used and 2) land transformation from non-arable lands to cropland is prohibited. However, these clarifications raised the following important concerns:

- First, when it goes to crops how do you distinguish between harvested area and planted area? There is no information for planted area for all crops. If harvested area is used for each crop, then what do you do with multiple cropping, crop failure. You cannot simply add up harvested area and say that the sum is total cropland. Please be very specific in your response.
- According to your response, non-arable land cannot be converted to cropland. You said some kinds of parameterizations were used. Please explain it more transparently and be very specific in your response. How about the revers land transformation: conversion of cropland to non-arable land? How do you model that? Please, again be precise in your response and avoid the general statement of based on profitability.

4. It is not clear how the estimation process is defined to estimate these parameters. Does the process estimate all the distribution parameters (s) simultaneously or individually?

Author Response: We are using Latin Hypercube Sampling, which estimates all parameters simultaneously.

Author Changes: We have added the following note to section 2.2: "Latin Hypercube Sampling draws all parameters simultaneously from uniform distributions."

Thanks, for this clarification. Please let me concentrate on the three logit distribution parameters and use the notation mentioned above. Based on this response and the response to my next comment, it seems the implemented process uses the following steps:

- Randomly selects three values for the three distribution parameters of $\rho^R, \rho^A and\ \rho^C$ from three uniform distributions (each ranged between 0.01 to 3).
- Given the selected parameters of $\rho^R, \rho^A and\ \rho^C$, land allocation for the whole time period is determined
- The above two steps repeated for 10,000 collections for each expectation type.
- A collection, including three distribution parameters, that minimizes the size of NRMSE is selected as the best estimate for the distribution parameters under each examined expectation type.

5. How distribution parameters () were perturbed? Are they coming from given distribution? If yes, what type of distribution? Is this a random selection of three values limited between 0.01 and 3?

Author Response: The parameters were sampled assuming a uniform distribution. For logit exponents, we choose values for each of the three exponents randomly between 0.01 and 3. Each of the three exponents can have a different value and we do 10,000 samples for each expectation type and model configuration.

Author Changes: We have added the following note to section 2.2: "Latin Hypercube Sampling draws all parameters simultaneously from uniform distributions."

Thanks for this clarification. See my previous response.

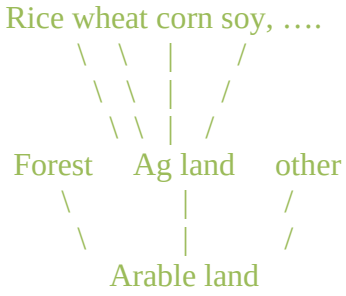
6. Over time total area of agricultural land in the US has declined sharply, due to conversion to non-agricultural uses of land (urbanization, infrastructure, ...). How gacamland handles conversion of land to non-forestry-ag land. How land availability land has been taken care off over time? Is it an exogenous variable in each year?

Author Response: While urban land has grown over time, the definition of urban land in gcamland accounts for only 1% of total land area in the United States. We hold this area constant in the simulations presented here (equal to 1975, 1990 or 2005 values depending on the calibration year used in the simulation). Allowing this to change over time would not have a noticeable impact on results given how small the area is. Similarly, we hold tundra and rock/ice/desert constant in time, but they account for very small amounts of land in the United States (2.6% and 0.4%, respectively). All other land is included in the economic competition.

Author Changes: We have added a footnote to the methodology section: "A small amount of land (~4%) is considered non-arable in gcamland in the United States, including urban, tundra, rock, ice, and desert. This land is held constant throughout the simulation time period."

Thanks for this clarification. However, it does not help and makes further confusion.

- The paper does not provide a clear picture of the land categories in the model. While you are talking about non- arable land as a part of land use modeling, the logit nesting structure does not cover it. If this type of land is not modeled, why it is described in the paper.
- Table 1 introduces three nests: Arable land; Ag land. Forest, and other; and Cropland (or crops). This plus other information provided in the tale bring in mind the following nesting structure:



However, there is no "*cropland*" in the middle nest. What is the relationship between Ag land, cropland, and pasture land? It seems a nest is missing.

- It is noted FAO data with some modification is used to determine land data. If that is the case, then something is not correct. Please let me explain. Arable land is a subset of cropland in the FAO data. For example, in the FAO data for 2018, area of US cropland is

160,437 thousand hectares with sub component of 157,737 thousand hectare of arable land. This is in a sharp contrast with the nesting structure defined in the paper. Also, area of US Ag land is 2.6 times of its arable land. How Ag land could be a subset of arable land?

The paper should make proper clarifications on this issue.

Finally, let us follow the nesting structure outlined in the paper. According to the FAO data, total area of US arable land has declined from 180,630 thousand hectares in 1961 to 157,727 thousand hectares in 2018, a decline by 22,893 thousand hectares. How this reduction has been handled? It is not a small reduction.

7. A big issue in land use modeling is marginal cropland (idled land under CRP, cropland pasture, other types of idled). Area of idled cropland in the US have changed a lot. The definition of "cropland pasture" has also changed over time. How idled land is treated?

Author Response: Idled land is called "Other Arable Land" in gcamland. The amount of land in this category can change over time based on economic signals. Since idled cropland does not produce a product, its profit rate is exogenously specified like other land cover types (see response to comment #12). Note that this exogenous value is similar to a CRP payment, as it represents a marginal benefit of keeping land fallow.

Author Changes: We have added a footnote to the methodology section: "Fallow cropland (called other arable land in gcamland) is also included in this nest." We have also added text to the supplemental material indicating that idled cropland is included in gcamland.

This is a misleading response. FAO data base does not have other arable land. Please at least, provide a table and put all types of included land in each nest at list for three years, including cropland and its components.

8. It is noted that harvested area from FAO is used. FAO is missing many feed crops since 2011, including million hectares of those crops. without proper steps to cover missing crops in FAO, the estimated parameters will be subject to major issues and biases. Figure three suggest that those feed crops is missed. That is a major issue.

Author Response: gcamland includes fodder and feed crops, using data from FAO prior to 2011. We have excluded it from the comparison and statistics because the data is not available after 2011 as you noted, but it is included in the modelled results.

Author Changes: We have revised the Figure 3 caption to clarify this: "Note that fodder crops are included in gcamland but are excluded from total cropland area in this figure due to data limitations." We have also added figures to the supplemental material showing all crops, including fodder.

This is a misleading response. If you fixed the data (for after 2011) by estimating the missing data items, then that should be reported and included in your figures. Transparency is the key.

9. GCAM is using commodity price to model land allocation. It seems wholesale farm prices is used. That is a bad proxy for exporting crops such as cone and soybeans. For example, half of soybean is exported at much higher price farm price.

Author Response: The producer price is the relevant price signal to be used for planting decisions. The market price, and thus the producer and consumer prices, is a function of the demand sectors as well, which includes domestic demand and exports. However, the resulting equilibrium price paid to producers is the relevant price regardless of how the demand is determined. Therefore, we feel that producer price is the right input into gcamland for this analysis.

Author Changes: We have revised the manuscript to better document what is included in gcamland. See also the responses to comment #1 and comment #19.

Yes, as it is noted in this response "price paid to producers is the relevant price", but the FAO whole sale price does not reflect the price received by farmers. You need to address this as a major limitation of your work clearly. Please explain what revision you have made? And be more specific.

10. In this paper, in one case, subsidy has been examined in a sensitivity test. Subsidy is the key item in deriving land use, land rent, and the price received by farmers. The distribution parameters of the logit should be evaluated with subsidies. Sensitivity test is meaningless. The key here is to capture all types of subsidies paid to famers in the estimation processes.

Author Response: As noted in the manuscript, the subsidy data does not improve the estimation either because these subsidies do not affect cropland area (as suggested by Weber and Key 2012 and discussed in Section 5.1) or due to the quality of the data. There are not continuous, complete, and consistent data sets for all types of subsidies paid to farmers. Additionally, we only found crop-specific information on direct payments, making the inclusion of other types of subsidies difficult.

Author Changes: We added more information to Section 2.4.2 describing the limitations of the data: "Subsidies are a reality of crop agriculture in the United States. However, there are not continuous, complete, and consistent data sets for all types of subsidies paid to farmers. Additionally, crop-specific information (of the type needed for gcamland) is only available for direct payments, making the inclusion of other types of subsidies difficult" and our choice to make this a sensitivity "Because this data is inconsistent and incomplete, we only use it as a sensitivity in this paper and do not include it in the primary analysis."

Thanks for this response. However, it is incomplete. The paper should clearly acknowledge that improper inclusion of subsidies could make major biases in the outcome of the estimation process and that a sensitivity test is not a proper way of fixing this issue.

11. How biofuels were included in the simulations? Biofuels and biofuel policies were major drives of land use. How that included in your simulations

Author Response: Biofuels and biofuels policy are reflected in our model through changes in producer prices of crops.

Author Changes: We have added this to the footnote explaining differences between GCAM and gcamland: "Changes in demand are explicitly represented in GCAM. In gcamland, changes in demand are captured through changes in price. For example, the increase in demand for corn and soybean due to biofuels policy is captured through changes in the prices of these goods."

This response makes me more concern. I am not convinced that your work properly identifies source of piece changes. You approach only consider changes in the prices and send that as a signal to the land supply tree, without identifying the sources of price change. The source of price change could be demand shock (e.g. biofuels) or supply shock (reduction in yield or land supply). You approach does not distinguish these sources and simply consider price changes as signals to the land supply. Can you convince the readers that you do not need to identify the source of price change?

12. Th dapper highlights that gcamland uses commodity prices in land allocation. But the model allocates land across land cover items. What prices are used for forest products, livestock products, etc.? The paper is silent on these prices. What prices were used for land cover items

Author Response: We calculate land rental prices for commercial forest and pasture using their product (forest or livestock products) prices and related productivity and cost information. For non-commercial land cover only items, effective profit rates are derived during the calibration process to ensure that the amount of land area in the base year predicted by the logit equation matches the read in value. For subsequent years, these effective profit rates are held constant. This estimation is described in detail in Wise et al. (2014).

Author Changes: We have added this information to the methodology section: "Profit rates (r_j) at the lowest level of the nest are computed based on price, cost, yield, and subsidy (if included) for land use types (crops, pasture, commercial forest); profit rates for land cover types are input into the model and are based on the value of land."

- This response makes no clarification. For example, it is said that: "We calculate land rental prices for commercial forest and pasture using their product (forest or livestock products) prices and related productivity and cost information." Please be very specific and answer the following: What are the prices of livestock products? How about prices of forest products? How do you measure yield for forest? How about yield for pasture land?

- If only arable land is modeled, why do you need profit rates for non-commercial land. As noted in my earlier comments, providing a table including all nests and their members could help.

- What is the effective rate for unmanaged forest? How do you determine it in the calibration prices? Calibration to what?

- The paper should clearly explain the above points

13. Regarding forestry, how gcamland treats forest land. Is it operates based on managed forest? Managed + unmanaged? How it treats unmanaged forest with no economic output.

Author Response: We include both managed and unmanaged forestland. For managed forestland, we use price and yield to calculate profit. For unmanaged, see response to comment #12.

Author Changes: See response to comment #12.

What are the price and yield of managed forest? How do you determine them? Based on what data do you calculate price of forest and yield of managed forest? The paper should explain these.

See also my response to comment 12 as well.

14. GCAM and gcamland are not forestry models. Forestry is not an annual crop. How these models take care of forestry in a dynamic setting. Do these models treat forestry as an annual crop?

Author Response: GCAM, gcamland, and other similar models assume that you need to set aside land at every timestep to ensure that you will have enough commercial forestland to meet harvest demand at the time the forest matures. To do this in GCAM, we assume that the amount of land needed for forest is equal to the wood product demand divided by the yield times the rotation length. So, if you need 1 Ha of land to meet wood product demand in a given year and the rotation length is 25 years, we set aside 25 Ha of land in that year. gcamland uses a similar paradigm, only we don't model demand, just yield and area. So, gcamland uses a yield that is equal to the harvest yield divided by the rotation length.

Author Changes: We have added this information to the methodology section: "Note that, since forestland is not an annually planted and harvested commodity, GCAM, gcamland, and other similar models assume that land must be set aside at every timestep to ensure enough commercial forestland is available to meet harvest demand at the time the forest matures. To do this in gcamland, we assume that the amount of land allocated to forest depends on the harvest yield and the rotation length."

Sorry for my ignorance. But I do not know any model that follow the assumption mentioned above. In your revision, please name some well-knows models that follow this approach. If I understand correctly, what mentioned above can be replicated by the following formula:

Forest area in year t = yield of forest in t * demand for forest in t * 25.

This formula over simplifies the way that a forest model works and has no root in real world. You need to put this formula in the paper and justify it to be transparent.

15. In each case, the model is solved for a range of parameters. Then a set of parameters that minimizes NRMSE is selected. But NRMSE is defined for a single crop. How this variable is aggregated over crops? How NRMSE is calculated for non-cropland (e.g. forest, pasture, grass land, and etc.)? How cropland and non-cropland aggregated?

Author Response: We take the average of crop-specific NRMSE to get the aggregated NRMSE. As noted in the manuscript, we do not include non-cropland in our calculation of NRMSE.

Author Changes: We have clarified this in the methodology by adding "For NRMSE and RMSE" before the sentence that describes the averaging across crops.

Thanks for these clarifications. I have difficulties to find out in what part of the manuscript it is noted that you do not include non-cropland in the calculation of NRMSE. Please clearly mention this point at the beginning of section 2.3 so that the reader can see this important limitation. Also, it is important to explain why you do not include non-cropland in the calculation. This is a surprise for me? Why you do not follow the same approach for other nest that you determine their distribution parameters. Indeed, as I mentioned before, you determine a selection of three parameters of $\rho^R, \rho^A and\ \rho^C$. But it seems you ignore how good are your estimated for $\rho^R\ and\ \rho^A$

and only care about ρ^C. In fact, you select a mix of $\rho^R, \rho^A and\ \rho^C$ to minimize NRMSE over the crop nest. So, this means that you may get bad errors for the other two nests while you minimize only over crops. This is a serous problem. Indeed, you do not optimize for two nests out of three nests. This could cause major errors in the projection of land use changes in the non-cropland nests, compared to the observed data.

16. How productivity of non-cropland is measured?

Author Response: We include productivity of pasture and forest, but not of other non-cropland types.

Author Changes: We have added this information to the methodology section: "Profit rates (r_j) at the lowest level of the nest are computed based on price, cost, yield, and subsidy (if included) for land use types (crops, pasture, commercial forest); profit rates for land cover types are input into the model and are based on the value of land."

Thanks for this clarification, but you did not answer the question completely. Please explain how did you calculated productivity of forest and pasture land? It is an important piece of information and the reader should know it.

17. GCAM aggregates crops into some specific categories? How prices were generated for those categories. In many cases there is no data on crop prices?

Author Response: We use the weighted average of producer prices for aggregated commodities, weighting by the production.

Author Changes: We have added this information to Section 2.4.2: "Data was aggregated from individual crops to the GCAM/gcamland commodity groups, weighting crops by their production quantity"

Thanks for the clarification, but for some crops, such as fodder crops, no data is available for quantity of production. Please explain what you did for those crops.

18. The paper provides mixed messages on endogenous and exogenous variable. In determining targeted distribution parameters, what variables were targeted and what variables were determined in the model. It seems prices, areas, and yields were exogenous. Be more specific.

Author Response: Within gcamland, prices, costs, yields, subsidies, logit exponents, and expectation parameters are exogenous. In addition, the land area in the calibration year is exogenous. Areas in subsequent years are endogenous. Within the experiment in this paper, we also varied logit exponents and expectation parameters as part of the ensemble sampling.

Author Changes: We have added this information to a footnote in the methodology section: "The land allocation mechanism within gcamland uses price, yield, cost, subsidy, logit exponents, expectation parameters, and initial land area as exogenous inputs and endogenously determines land area in subsequent years."

Thanks for this clarification.

19. The whole practice implicitly assumes that other model parameters are accurate and valid. This is a strong assumption. The land supply parameters were determined while demand parameters held constant. The estimated supply parameters will be entirely wrong if the demand parameters (e.g. income and price elasticities for crops, livestock products, and forestry) are not valid. Any change in the demand parameters could alter your estimated parameters for the land supply. Can you test sensitivity of your results with respect to changes in other elasticities of the model?

Author Response: As noted in our response to comment #1, gcamland does not include a representation of demand for the exact reason you note here. We have chosen to isolate the land allocation mechanism in gcamland to ensure we get the right parameters for the right reasons and do not have cancelling errors. We cannot do a sensitivity on demand elasticities since they are not included in the model at all. Price is the only link to demand and we are using observed prices from FAO to ensure that demand-side sensitivity and errors do not affect the parameter estimation on the supply-side.

Author Changes: See response to #18.

Please see my response to item # 11

20. The results are counterintuitive. Let me explain using figure 2. In the adaptive case, for the first two nests the values are about 0.4 and for the last nest (cropland) the value of is about 0.6. Given that limited land movements among land cover items occurred at national level in the US and lots of change occurred in the crop nest, one could justify this outcome. However, for the other three cases (hybrid, linear, and perfect) the ranking is of values shows revers. Meaning that land conversion is easier at the land cover nests than the cropland land nest. These outcomes do not make sense. Am I missing something?

Author Response: Those outcomes also get lower NRMSE than the adaptive expectations, indicating that they do not explain historical land allocation as well as adaptive expectations. The parameter sets for hybrid, linear, and perfect minimize NRMSE *if those expectation types are assumed*, but the model with the lowest NRMSE includes adaptive expectations and parameters that match our intuition.

Author Changes: An explanation of the results and intuition is provided in section 4.1.

Thanks for this clarification.

21. In showing the results, level variables were used to show errors. For example, figure 2 compares estimated harvested areas with their observations for four types of expectations. This hides the errors involved. It is better to calculate errors as percent difference between the estimated and observed areas.

Author Response: Thank you for the suggestion. We have considered adding a figure on percentage difference to the paper (attached). However, we feel that showing absolute values compared to observations is more informative since it gives a sense of scale, which differs significantly across crops in the USA.

Author Changes: We have added figures comparing model results to observations for all commodities to the supplemental material, but have opted not to add figures showing percentage

difference.

This is not an appropriate response. It is an essential task to inform the readers regarding the percent errors between projections and observed values. Comparing the level variables in a chart hides those errors. to be transparent and informative you need to provide data on errors. If it is hard to show it in charts, please show them in a table in the appendix. This is an essential validation check.

22. The main manuscript only presents comparison of the projected and observed harvested areas and provided no comparison for other land types.

Author Response: The comparison of projected and observed area for other land types is included in the supplemental material for types where observations are available.

Author Changes: The comparison of projected and observed area for other land types is included in the supplemental material for types where observations are available. We have also added a paragraph to the supplemental material stating which land types are in gcamland and explaining our choice of what to show where: "The main text of this paper focuses on four commodity groups (Corn, Wheat, OtherGrain, and OilCrop), as these four commodities represent the largest land area in the United States. However, gcamland includes twelve commodity groups in total, representing all crops reported by the FAO, and fallow or idled cropland (referred to as other arable land in gcamland). In addition, gcamland includes commercial forest and pasture, as well as several other land cover types, including forest, grassland, shrubland, tundra, rock/ice/desert, and urbanland. We include results for other agricultural commodities and the land cover types where observations are available in this section"

Sorry, I do not consider this as a satisfactory response. The paper and its supporting material provide inconstant and confusing information about the land cover types, land uses, and components of each of the three nests included in the model. Simply revise table 2 and clearly put all land types and land uses in that table for each nest.

For example, in the main text in table 2 pasture land is not a part of middle nest. But it appears in the SI in Figure 7 as a component in the mix of grassland, shrubland, and pasture. Very confusing.

The main text should clearly represent the nesting structure and the component of each nest. Do not refer to another paper. This is an essential information for this paper.

Figure S7 should show data for each land cover item including managed forest, unmanaged forest, pasture, grassland, shrubland, any other components of the non-cropland nest, and cropland as one land cover type. If your model does not trace changes in some land types, that type of land should not be included in the model nor in the paper.

As a subcategory of cropland, the projections for unused cropland and their corresponding observations should be presented and compares.

23. Results are highly aggregated into four groups of crops. how about the 12 categories of crops in GCAM?

Author Response: The main manuscript shows four of the 12 crop categories. We have included

figures showing the other categories to the supplemental material.

Author Changes: The main manuscript shows four of the 12 crop categories. We have included figures showing the other categories to the supplemental material. We have also added an explicit reference to these figures in the main text.

Please, add changes in unused land. That is an important piece of information.

24. The figure S5 of SI shows major errors for the change in forest area. This show that the model fails to represent changes in forest area correctly.

Author Response: Figure S5 had included the net change from 1990 to 2015 for the modeled data and the net change from 1992 to 2015 for observations for forest. Figure S7 shows the whole time series. As shown in S7, the time series tracks the observations fairly closely for the adaptive expectations. We do not think it is correct to say that the model fails to represent changes in forest area; however, we do think that Figure S5 was confusing given the unit used and the differences in time horizon.

Author Changes: We have removed Figure S5 as it did not add any new information and was confusing (see response to comment #25).

First thanks for adding figure S7. Adding this figure is a step forward. As I mentioned in comment # 23 you need to extend this figure for all land cover items. In particular, it is important to show errors in %, not in levels. Level variables hide errors. Please show the percent errors, then we can judge the model performance in land cover items. Also remember that you failed to calculate the goodness of fit (in your language NRSME) for land cover items.

Figure S7 shows bad performances for land cover items that already are included in this figure. In particular, I see very large differences in level variables between the performance and observed items. You also could alter the scale of this figure to better see the errors for forest. You should show the errors in percent to show the model performance. I believe it is straight forward to calculate NRSME for these items. Why not?

25. The figure S5 show increases in all land cover types and harvested areas. How that could be possible?

Author Response: Figure S5 shows the ratio of land in 2015 to land in 1990. Values less than 1 indicate a reduction in land area over time. There are several land types where area declined and those land types have values less than 1. However, we do think the unit used in this figure was confusing and all of the information contained in this figure is also shown in Figure S7, so we have removed this figure.

Author Changes: See response #24.

Thanks, see my responses to item # 24

26. Figure S7 shows no results for land cover items including grassland and shrubland for three types of expectations. Why?

Author Response: These results are included but they are covered by the line for adaptive expectations. All four expectation types produce similar values.

Author Changes: We have improved the figure so that the other expectation types are visible and added a note to the caption indicating they are overlapping.

Thanks

27. Figure S7 shows major errors for grassland and shrubland in the adaptive approach project huge errors. Why?

Author Response: This is due to differences in the definition of grass and shrubland between gcamland and the CCI land cover product. Most notably, gcamland includes a large portion of what is categorized as grass or shrub in CCI land cover as pasture.

Author Changes: This was already stated in the paragraph immediately preceding figure S7: "Due to differences in definitions of land cover between gcamland and the CCI land cover product, Grassland and Shrubland do not match in absolute value between gcamland and the observation data." We have also added a panel to this figure showing the sum of pasture, shrubland and grassland; this summation improves upon the data mismatch.

Sorry, but this response does not make sense. If you used different definitions in your modeling practice, you should adjust the actual observations based on your definition as well. please revise accordingly. Even the combined panel shows large differences. We are talking about millions of km^2.

28. It seems the whole practice has failed to take care of land cover changes.

Author Response: Land cover changes are included in gcamland and are compared to observations in the Supplemental Material. Therefore, we do not think it is correct to say that we have failed to take care of land cover changes.

Author Changes: See changes in response to comments 12, 13, 16, 22, 24, 25, 26, 27.

I already responded to these. Your work fails to calculate the goodness of fit for land cover items. That should be highlighted in the main manuscript, as I highlighted in several places in my responses. Also, errors should be presented in % differences. This is an essential item to validate this work. given the size of land items, even 5% error is huge. We are talking about million hectares of land.

29. The examined practice estimated a few parameters of the model for land use. A good way to test the outcomes of this practice is to run the GCAM model with the estimated parameters and compare the model results for land use changes, land cover changes, changes in crop prices, and changes in yield with actual observations over the examined period.

Author Response: We agree that this is a useful test and intend to do it in subsequent work. However, this paper is focused on parameter estimation and we think that adding those simulations to this paper would unnecessarily complicate the existing text and analysis.

Author Changes: None.

I am glad that you consider this test as a useful test. But it is not only useful. This is an essential task. Validation of estimated parameters is a crucial task. Indeed, without this test you do not know how good the estimated parameters for projection are. Running a validation test may require more work, but it is an essential task.

I observe that the revised version noted that: "we have focused on the historical period. However, these models and parameter estimates could be used in a simulation of future land use and land cover change to better understand their implications." Even you have not shown how your model project historical data. You only used historical data to estimate the logit parameters. But failed to test how good are the estimated parameters to replicate the historical. That should be clearly acknowledged in the paper.

If you choose not running this test, then the paper should clearly acknowledge that you have not examined the validity of your practice in the abstract, discussion section, and conclusion.

30. Finally, the whole work could be a valuable practice for the CGAM community. It uses "hindcast" to estimate the logit distribution parameters for this model. Hindcast Is not a new approach. The outcome of this practice may help the GCAM community to improve their work on land use modeling. However, the results of this practice may be not useable for other models. As they may follow very different modeling structure and assumptions. The author of this paper should make this point very carefully.

Author Response: We agree with the reviewer's notes here. Other models can use from our methodology and some of the takeaways from this paper (e.g., the choice of metric and which crops to include can alter the resulting parameters and model performance); however, other models are unlikely to be able to use these parameters directly.

Author Changes: We've added this caveat to the discussion.

Thanks

31. The abstract provides trivial information. It is not an abstract of this paper.

Author Response: We have revised the abstract.

Author Changes: We have revised the abstract.

With all due respects, the revised abstract needs a major work. The fist six lines provide a lecture to justify this work. Those should be included in the main text not in the abstract. Then it is noted that: "We run gcamland simulations with these parameter sets over the historical period in the United States to quantify land use and land cover, determine how well the model reproduces observations". This is not what you did. you have not quantified "land use and land cover" over time. You used historical data to estimate some model parameters. You have not determined how your model produces actual observations for the estimated parameters. This is the validation test that you refused to accomplish. You have not highlighted your findings on the sizes of the estimated parameters. You have not highlighted the limitations of this work. You need to revise the abstract.

32. Following a summary of land use change at the global scale, the second paragraph of the

introduction begins with: “Similar trends occurred in the United States”. This is not an accurate statement. The US land use change did not follow the global land use changes in terms of land conversion to crop production. No expansion in cropland has been observed for the cases of US.

Author Response: We have removed that sentence.

Author Changes: We have removed that sentence.

Sorry, why you removed this part. You have to correct your statement and say that the United States have not followed the common trends in other countries and inform the reader why not.