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# *Interactive comment on* "Modeling Land Use and Land Cover Change: Using a Hindcast to Estimate Economic Parameters in gcamland v2.0" *by* Katherine V. Calvin et al.

**Katherine V. Calvin et al.**

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Anonymous Referee #1

GENERAL COMMENTS In this manuscript, Calvin et al. conduct a large ensemble of simulations for the United States with the gcamland land use model to optimize model structure and parameters related to landowner decisionmaking. They find that an adaptive expectation structure performs best, in contrast to the linear structure previously used in GCAM. The authors also test the sensitivity of the optimization to various setup choicesâĂŤincluding objective function, timestep, and calibration yearâĂŤfinding that, where the results are not robust across setups, they differ in mostly predictable and



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understandable ways. This manuscript represents two important contributions to the development of gcamland, which seem to not often be explored by other land models: The challenging of the model with historical data, and the testing of alternative structural formulations. (I am admittedly not familiar enough with the land use modeling literature to say for certain that the authors have included all relevant previous work in their review of previous literature, however.) It also provides a useful blueprint through which similar work could be performed for other land models. The manuscript is well-written and clear from the introduction through the conclusions, although I have some minor comments and suggestions (listed below). I thus recommend that this manuscript be accepted subject to minor revisions.

Author Response: Thank you for your feedback and helpful suggestions.

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.

SPECIFIC COMMENTS - The authors should better tie the paragraph at lines 69–79 (re: previous attempts to parameterize land use models based on real-world information) into the rest of the paper. In the following paragraph, they could more explicitly lay out the novelty of their work relative to what's been done before in this area. Then, in section 2.1.2, they should tie back more explicitly into the idea of elasticity, which is how they characterize much of the work pointed to at 69–79.

Author Response: Thank you for the suggestion. We have made both suggested changes.

Author Changes: We have added "we advance the science on parameterizing land use models by using statistical approaches rather than the heuristic approaches described in the previous paragraph" to the last paragraph of the introduction (starting around line 83). We have also added text in 2.1.2 to tie the approach in gcamland to the land supply elasticity: "These parameters influence the land supply elasticity, which is non-constant (i.e., it varies depending on the relative profitability as described in Wise et





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al., 2014)."

- Did the authors use any R (or other) packages to perform the Latin Hypercube sampling and/or to evaluate the results? If so, it would be helpful for reproducibility to specify those.

Author Response: We used the R lhs package for the sampling. We also use the R stats package for analysis.

Author Changes: We have added this information to the methodology section of the paper.

- Fig. 4 needs at least one other marking on the X-axis. Ideally, match Figs. 5 and 6.

Author Response: Thank you for the suggestion.

Author Changes: We have added additional x-axis labels.

- L334: "the difference in the bias area volatility" is confusing. Maybe a word is missing?

Author Response: We agree this was confusing.

Author Changes: We have revised this phrase to say "the difference in the cropland area volatility when bias is minimized"

- Fig. S2: A 1:1 line would be helpful.

Author Response: We have added a line.

Author Changes: We have added a line.

- Fig. 6: It would be helpful to have the thick lines below the rest, since that would allow the thinner lines to be seen even when they overlap it (which they frequently do).

Author Response: Thank you for the suggestion.

Author Changes: We have made this change.





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- Fig. S11: Middle panel only includes bars for "5 year timestep (RMSE)" because that was the only setup where the error-minimizing setup used that parameter, right? That should be mentioned in the caption.

Author Response: We used RMSE to compare results from the 1-year timestep model configuration to the 5-year timestep model configuration. We chose this instead of NRMSE because NRMSE normalizes by standard deviation which will change depending on timestep.

Author Changes: We have added an explanation to the caption.

TECHNICAL CORRECTIONS - Lines 152–153: NRMS should be changed to NRMSE for consistency with the rest of the manuscript.

Author Response: We have made this correction.

Author Changes: We have made this correction.

- Fig. 3: "... fodder crops *are* excluded..."

Author Response: We have corrected the grammatical error in this sentence.

Author Changes: This phrase now says: “fodder crops are excluded from. . .”

- L329–330: Units should be added to the first part of the sentence. Additionally, it feels weird to say "the parameter sets... result in an average observed Corn area", as the parameter sets don’t have anything to do with the observations.

Author Response: Thank you for catching this.

Author Changes: We have added units to the first part of the sentence. We have also revised the sentence to say link the parameter sets to simulated area only: “the parameter sets that minimize bias result in an average simulated Corn area of 307 thous km2 compared to an average observed Corn area of 306 thous km2. . .”

- Figs. S4, S5, S7, S9, S12, and S13 should be mentioned in the main text.





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Author Response: We have added references to all supplemental figures in the main text.

Author Changes: We have added references to all supplemental figures in the main text.

- Rounding inconsistencies between Sect. 5.2.1 and Table S3 should be corrected.

Author Response: We have corrected these inconsistencies.

Author Changes: We have corrected these inconsistencies.

- "Ag, Forest, and Other" is referred to in the Supplement as "AgForest_NonPasture". Ideally, one should be chosen for consistency.

Author Response: We have corrected this.

Author Changes: We have updated the Supplement to say “Ag, Forest, and Other”

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.

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





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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."

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 equa-





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tion 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 (rj) 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 (rnode) are determined by: r_node= [$\sum$_($j = 1$)$n$($\lambda$_j r_j )ˆ ]ˆ(1/)..”

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.”

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.”

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?





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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.”

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 ($\sim$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.”

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?





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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.

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.

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,





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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.

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."

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





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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.”

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 (rj) 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.”

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 man-





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aged forestland, we use price and yield to calculate profit. For unmanaged, see response to comment #12.

Author Changes: See response to comment #12.

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."

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?





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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.

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 (rj) 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.”

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”

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





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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.”

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.

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





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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.

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.

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





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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”

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.

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





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and was confusing (see response to comment #25).

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.

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.

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





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data mismatch.

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.

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.

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





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performance); however, other models are unlikely to be able to use these parameters directly.

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

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.

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.

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Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-338, 2020.





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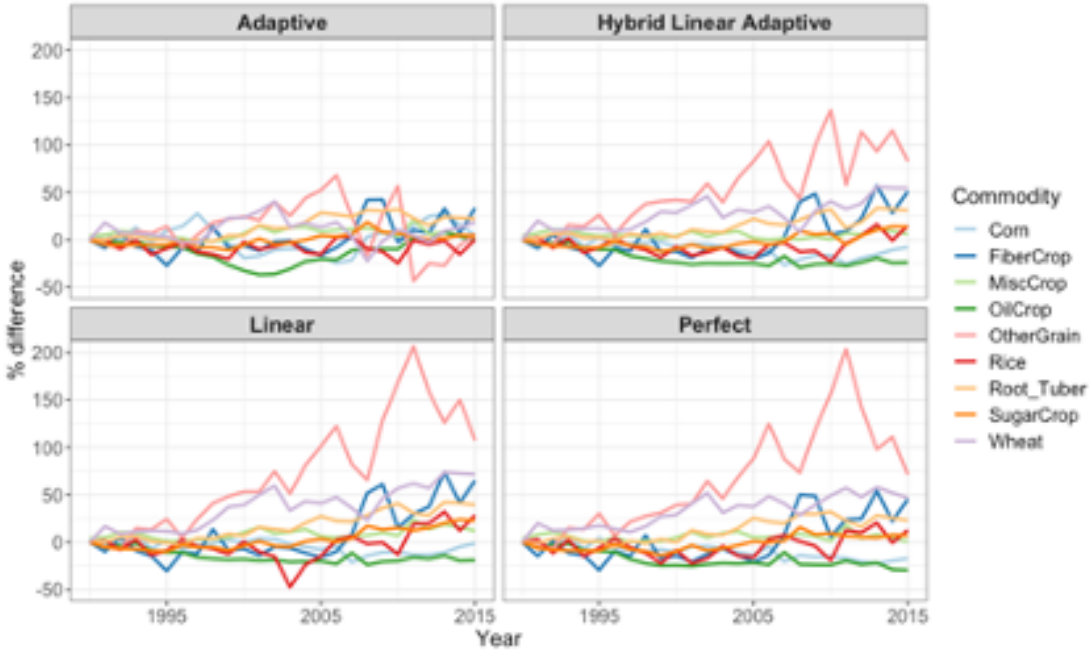


**Fig. 1.**

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