Major comments	
Comment	**Response**
Clarification of Figures 7 and 8: Could the author clarify why the gridded differences are primarily influenced by the specific factors highlighted in Figures 7 and 8, rather than other potential variables? On Lines 438–441, the manuscript states: "One of the primary explanations for the effect of harmonization on forests is the different inputs regarding forests among the LUMs and LUH2 historical maps used in harmonization, especially in areas with intermediate tree cover. For example, global forest areas in 2000 range among different satellite sources and FAO between 3600 and 4300 million hectares (Ma et al., 2020)." While this provides some explanations for the effect of harmonization on forests, more detailed explanations of the dominance of the factors shown in Figures 7 and 8 would be helpful for better understanding.	Given the level of detail reported by the land-use models before and after harmonization, we focus on the factors corresponding to the categorical variables available. Our central assumption is that the primary sources of variance stem from (1) uncertainties in the GCMs used to generate the impact data, (2) differences in the processes, inputs, and modeling approaches of the various land-use models, and (3) assumptions underlying the scenario representations. Incorporating additional variables would require re-running the models and conducting further tests. However, as the primary aim of this study is to highlight the sources of uncertainty in the data presented rather than to comprehensively analyze differences among land-use models, such tests fall outside the scope of this work. We will clarify this in subsection 2.4.3 (Methods) and subsection 3.3.2 (Variance analysis on the global scale), referring to the studies by Schmitz et al. (2014) and Nelson et al. (2014), which delve more deeply into differences among land-use models. However, to further expand on the discussion in section 3.3.2 regarding differences among land-use models and factors—including inputs, definitions, and processes—we will add a supplementary table in Annex A. This table will detail the land-use variables explored in this study, clarifying their input sources, definitions, and calculation methods, for the two models and their treatment during harmonization. This addition will provide further transparency and context for our analysis.
Comparison of ISIMIP3b and LUH2 Datasets: The manuscript compares the ISIMIP3b LUC with CMIP6 LUH2 data in various instances, such as on Lines 287–289: "This drop in demand for second-generation bioenergy crops is related to changes in the mitigation assumptions of SSP1-RCP2.6, which involves updated impacts on yields." This is informative, but could the authors provide a more detailed explanation of the core differences between the ISIMIP3b and LUH2 datasets, and explain how these fundamental differences contribute to the observed discrepancies? This additional context would help the reader better understand the significance of ISIMIP3b LUC and understand why it differs from CMIP6 LUH2.	The following explanation will be added to the Methods section to clarify the differences between the LUH-CMIP6 and the ISIMIP3b datasets generated by the Land Use Models (LUMs). LUH2-CMIP6 data differs from the ISIMIP3b data in that LUH2-CMIP6 does not account for CO_2 fertilization. Additionally, LUH2-CMIP6 combines outputs from multiple land-use models for different scenarios, introducing variability in dynamics based on the models used. Another key difference lies in the inputs of the LUH2 harmonization algorithm, as the historical datasets used in ISIMIP3b have been updated compared to those in LUH2-CMIP6. Additionally, a new representation of protected lands to better match the IAM assumptions was included. There are also notable differences in the versions of the models employed. For MAgPIE, the version used for CMIP6 simulations was 3.0, while ISIMIP3b utilized version 4.4.0. The latter (starting from MAgPIE 4.0) introduces several enhancements, most notably, a food demand model that accounts for detailed dietary composition, food waste, and demographic characteristics. MAgPIE's used version used in this study also improves spatially explicit outputs by incorporating the accounting of capital stocks and their depreciation, and a more detailed representation of the forestry sector. Similarly, for IMAGE, the version used for ISIMIP3b was 3.3, whereas version 3.0 was used for LUH-CMIP6. IMAGE 3.3 includes more crop categories, advancements in modeling bioenergy, deforestation, land-based mitigation, and improvements in water use modeling.

Explanation of Equation 2: Please explain how interaction is defined and how the interaction calculation is conducted.	The residual term—"interactions" in Equation 2 for this study—represents the portion of variance the independent variables (GCMs, RCPs, LUMs) cannot explain. This interpretation, where residuals are equivalent to the interactions, is particular to this type of study due to the deterministic nature of our data (the LUM models are deterministic). Since the factors and total variance (as a sum of squares) can be derived from the data, the difference between the total variance and the variance explained by the factors reflects the effect of the residuals or interactions. This component captures the non-additive or nonlinear contributions to the variance. If the residual/interactions term is significant compared to the other factors, it highlights the complexity of the relationships between the dependent and independent variables. Equation 2 simplifies highly complex systems, spanning climate, crop, energy, and land-use models, as the workflow diagram shows. Therefore, a significant contribution from the interactions term highlights the varying sensitivities and complexity of modeling different land-use variables and the effect that climate impacts and socioeconomic growth assumptions have on them. We will add this clarification to the Methods section (2.4.3 Variance analysis) and in the results of the variance analysis in section 3.3 (Variance analyses).
Uncertainty from Land Use Downscaling: The land-use downscaling process could introduce uncertainty into the gridded LUC. I suggest the authors could discuss this uncertainty in the discussion section	We will add more information about how models disaggregate their data to spatially explicit levels and sources where detailed information can be found in the models' description in the methods section (subsection 2.1) and possible implications in section 4 (Conclusions and Discussion). **In methods:** Disaggregation of land-use patterns in IMAGE relies on gridded potential yields from LPJmL, data from the previous step, a regional management factor, and an empirical allocation algorithm. The process begins with calculating potential cropland and crop production data in the current time step using the patterns from the previous step. If production is insufficient to meet demand, less productive areas are abandoned, whereas cropland expansion employs the empirical allocation algorithm that evaluates cropland and grassland allocation. More information is available in (Doelman et al., 2018). In MAgPIE, land-use disaggregation is based on the previous step patterns, available cropland, and a mapping between the high and low resolutions. At each time step, starting with cropland, changes in land use from the clusters are disaggregated using expansion and reduction weights and information about land availability. Detailed information can be found in the interpolateAvlCroplandWeighted function from the R library Lucode developed by the MAgPIE team (Dietrich et al., 2024). **In the discussion section:** Disaggregation of LUMs outputs to high-resolution levels plays a critical role in determining spatially explicit land-use outputs in LUMs and could contribute to uncertainty. However, during the harmonization process, the original gridded data reported by the LUMs is aggregated to a 2°×2° resolution and subsequently disaggregated using the approach described in Hurtt et al. (2020). Adopting a consistent algorithm in this step could help minimize allocation differences in the higher-resolution harmonized data due to downscaling.

Minor comments	
Comment	**Response**
Lines 447-448: "However, we found some differences regarding the regional and local distribution of land-use change, specifically in cropland for the LAM region." Please explain why this difference in cropland occurs.	We would expand this sentence as: "However, we found some differences regarding the regional and local distribution of land-use change, specifically in cropland for the LAM region, due to a higher demand for bioenergy crops in this area in MAgPIE, as it can be seen in Figure B3". Further context to differences in bioenergy demand will be added as suggested for the Minor comment regarding differences in allocation and demand for bioenergy cropland area below.
Lines 69-70: "... which has commonly been used for impact analyses in global and regional studies. (Yu et al., 2019; Qiu et al., 2023; Hoffmann et al., 2023)." Please check if the period before the parentheses needs to be removed.	We will review the appropriateness of the period before the parenthesis, considering the journal guidelines.
Lines 448-450: "For SSP5-RCP8.5 and SSP3-RCP7.0, global and regional trends disagree regarding the direction of change in grassland area, which leads to differences in forests and natural vegetation." Please explain the potential reasons behind this.	To approach this comment, we will add the following paragraph in the discussion and conclusions section: "A possible explanation for this behavior is the expected increase in livestock products in the SSP5-RCP8.5 and SSP3-RCP7.0 scenarios. Higher demand for meat and dairy products leads to a greater need for grasslands and crops used as animal feed. Both models account for the feed mix required to meet animal energy needs, considering factors like production systems types and feed conversion. However, how these demands and shares of the feed mix are estimated differs between the models, which can lead to varying projections for grassland use. On the one hand, in MAgPIE, grassland intensification and reliance on crop-based feed sources reduce the need for grassland expansion in scenarios with high demand for livestock products. On the other hand, although IMAGE moves to more intensive livestock systems as well, the share of grass in the feed mix stays relatively high—especially in SSP3-RCP6.0—resulting in a grassland expansion. For information on livestock systems modeling in IMAGE, refer to Bouwman et al. (2005); Lassaletta et al. (2019), and for MAgPIE to Weindl et al. (2017a, b)"
Figure B2: Did the study consider changes in pasture and forest yield in addition to crop yield?	Changes in pasture yields and forest carbon densities under different climate change pathways (RCPs) are included in the inputs of the land-use models. Lines 137-141 will be modified to clarify this. "Each simulation utilized biophysical data that captured the impacts of the different climate change pathways (RCPs) on cropland and pasture yields, irrigation requirements and blue water availability, and carbon stocks—changes in carbon stock data applied to natural and planted forests. The impact data was derived from internal (IMAGE) or external (MAgPIE) LPJmL computations."

Line 460: "On the one hand, for example, LUMs have been used to conduct studies focused on China, India, or the European Union, which has involved further development and validation of the models' outputs for these countries/regions (Singh et al., 2023; Wang et al., 2023; Veerkamp et al., 2020) on different resolutions." Are these popularly studied regions showing better consistency among LUMs?	This comment made us aware that the original sentence could be misunderstood. It is important to clarify that individual models have been used to conduct the studies focusing on specific regions and have been validated using databases such as FAO, national datasets, or expert knowledge. Consequently, some regions mentioned may have been studied in depth by only one model. We will revise the sentence as follows: "LUMs have been used to conduct region-specific studies. For instance, MAgPIE has performed assessments focused on China (Wang et al., 2023) and India (Singh et al., 2023), while IMAGE has examined the European Union (Veerkamp et al., 2020). These studies have involved further development and validation of the models' outputs for these specific regions. It is important to note that China, India, and Europe are among the largest producers of agricultural commodities—often referred to as 'breadbaskets'—and have received considerable attention from the agricultural and food system scientific community. In our study, as shown in Figure B9, the coefficient of variance in these regions, particularly for cropland area, fertilizer use, and irrigation, is relatively low compared to other areas. This remains true even under scenarios such as SSP3-7.0 and SSP5-8.5 toward the end of the century. These findings highlight the importance of expanding research to less-studied regions and land-use variables."
Lines 465-467: "Second-generation bioenergy crops (Figures B7, B10-B13) are generally allocated in concentrated and highly fertile areas across all scenarios. These areas primarily include the west coast of Australia, southern Brazil, the Eastern European Plain (especially in SSP1-RCP2.6), Southeast Asia, southern China, and West Africa." Please explain why these differences in bioenergy crop allocation occur.	This question addresses two aspects: (1) the allocation of second-generation bioenergy crops (lines 365–370) and (2) the difference in the peak of bioenergy demand in the SSP1-2.6 scenario (lines 466–468). We will include the following information in subsection 3.2.5 (Second-Generation Bioenergy) and section 4 (Discussion and Conclusions), respectively. **Allocation of Second-Generation Bioenergy Crops:** Future demand for bioenergy is expected to be high in the SSP1-2.6 scenario due to its role as a mitigation option -specifically in the second half of the century - as we can see in the analysis of global trends, leading to larger areas allocated for bioenergy crops. Unlike other land-use variables, land-use models (LUMs) do not include initial maps of second-generation bioenergy cropland for the historical period. Thus, differences in allocation arise from the absence of historical data on dedicated cropland locations and the distinct allocation rules of each LUM. Both models allocate bioenergy crops based on biophysical suitability. However, in MAgPIE, bioenergy crops must compete with other land uses and crop types, and since REMIND determines regional demand and trade flows, each region must fulfill its requirements in the land-use model. In contrast, in IMAGE, they are confined to abandoned agricultural lands or, when insufficient, to natural grasslands. **Peak Differences in Bioenergy Crop Area:** Previous studies, such as in Popp et al. (2014), suggest that differences among models regarding bioenergy prices, energy deployment levels and make-ups, yields, assumptions about economic and technological growth, biomass resources, and sensitivities to other variables can explain this behavior.

Lines 319-321: "More specifically, MAgPIE's cropland allocation is based on minimizing production costs and local biophysical constraints, while IMAGE's approach relies on a constant elasticity of transformation function, which associates land supply responsiveness with changes in yields and prices (Schmitz et al., 2014)." Could the author elaborate on how these model differences contribute to variations in the LUC results?	As noted earlier, additional information is needed to understand better the effects of different parameterizations and factors on the models' outputs. Thus, to address this comment, we expand the discussion by building on insights from previous studies. The following explanation will be incorporated into the discussion, together with the sentence in lines 319-321: "While both MAgPIE and IMAGE simulate the land-use system by accounting for future socioeconomic, biogeochemical, and biogeophysical changes, they differ in their setups. These differences may partly explain discrepancies in global projections for cropland and grassland areas under some scenarios, as well as the significant influence of the LUM factor on variance for certain variables at spatially explicit levels. A key distinction lies in the economic modeling approach. MAgPIE is a partial equilibrium model focused on the agricultural sector, whereas the IMAGE framework uses the CGE model MAGNET, which accounts for the entire economy. Additionally, MAgPIE's cropland allocation is based on minimizing production costs and local biophysical constraints, while IMAGE's approach relies on a constant elasticity of transformation function, which associates land supply responsiveness with changes in yields and prices (Schmitz et al., 2014). Previous studies, e.g., Alexander et al. (2015), have shown that CGE models often project lower cropland areas. This outcome is likely due to factors such as input substitutability, interactions between agriculture and other economic sectors, and their resulting effects on prices, demand, and supply of agricultural commodities and inputs. Another major difference involves the use of the LPJmL model. MAgPIE employs LPJmL outputs as exogenous inputs, while IMAGE integrates LPJmL dynamically. As Doelman et al. (2022) highlighted, the dynamic coupling of crop, hydrological, and vegetation models can influence estimates, leading to variations in projected biophysical conditions on the spatially explicit level under similar scenarios. Finally, the approach to technological change (TC) is another critical factor. TC directly impacts yields for cropland and grassland, which, in turn, affects land demand and competition, contributing to variations in land-use projections. For further details on the key processes modeled in IMAGE and MAgPIE, please refer to Table A1."
Region Division (Figure B1): The globe is divided into five regions in the manuscript (Figure B1). Please explain the criteria for this division.	Since MAgPIE and IMAGE perform simulations using different regions, we selected five mega-regions to illustrate regional trends. Specifically, we used the so-called SSP regions, which have been widely applied in studies involving the Shared Socioeconomic Pathways (SSPs) and climate change, e.g., in Popp et al. (2017); Bauer et al. (2017); Meinshausen et al. (2020) and Fu et al. (2021). This clarification and the references will be added to the Methods section (subsection 2.4.1) and summarized in the caption of Figure B1.
Figure B2 Placement: Given the importance of this modeling protocol, I suggest moving Figure B2 into the main text.	Figure B2 will be moved to the Methods section, specifically to Section 2.1 (Land-Use Models) where the land-use models and their inputs are described.