Reviewer1

Comment #1-0

This paper presents a new global 1km fractional urban change dataset for the 2015-2100 period. It is the first global fractional urban change dataset that I am aware of, which should make it of high interest to the Earth and Environmental Science community. The methodology used was adapted from previous methods developed by the authors to allow for fractional (rather than binary) urban change modelling. The model validation results (e.g., RMSE = 0.08) are encouraging, although I request the authors to explain the calibration/validation procedure in more detail (see my Specific comments 4-5). The manuscript is generally well structured and readable, but could use a language and grammar check. Overall, I believe this paper is a valuable addition to the scientific literature on urban change, and that it could be publishable after further revisions and clarifications by the authors.

Response: thank you for the positive comments and valuable suggestions. As suggested, we have carefully revised the methodology part (especially in the calibration/validation) and checked the grammar in our updated manuscript. The detailed point-by-point response is presented below.

Comment #1-1

Page 3, line 10: "Although several global datasets of urban extent dynamic with conversions from non-urban to urban have been proposed, there is still limited effort to characterize the gradual urban fractional change (i.e., ISA) within each grid when projecting future global urban sprawl (Potere et al., 2009; Huang et al., 2021; Herold et al., 2003; Seto et al., 2012; Li et al., 2017)". I suggest to include more information on some of these other global urban extent datasets, e.g., their spatial resolution, the data used to calibrate/validate the model, the years for which the data is available (e.g., to 2050? 2100?). Also, you may want to note if any are not freely available for download. This additional information can help to highlight the other advantages of your dataset (aside from its mapping of fractional cover).

Response: thank you for your suggestions and questions. As suggested, we included information of other global urban extent modeling work in our revised manuscript (*Chen et al., 2020*; *Gao and O'neill, 2020*; *Zhou et al., 2019*). In general, the spatial resolution of these products is either relatively coarse (e.g., 8km; *Gao and O'neill, 2020*) or only available in binary format (1km; *Chen et al., 2020*; *Zhou et al., 2019*). Moreover, limited attempts have been made to fully explore the temporal dynamics of urban evolution from long-term and annual urban extent time series data (*Chen et al., 2020*; *Gao and O'neill, 2020*), which could introduce noticeable uncertainties in projecting future urban growth. Yes, these datasets are free to download. We improved our descriptions in our revised manuscript as below.

"However, the spatial resolution of these global urban products is either relatively coarse (8km) (Gao and O'neill, 2020) or only available in binary format (1km) (Zhou et al., 2019; Chen et al., 2020a). The temporal contexts of urban sprawl were limitedly considered in these studies, leading to noticeable uncertainties regarding the projected global urban extent dynamics in the future with long-term historical urban sprawl." (Page 3, Line 13-16)

Comment #1-2

Page 4, line 15: It would be beneficial to readers if you can explain why the global artificial impervious area (GAIA) dataset was used for this model calibration and validation. For example, are there no appropriate ~1km fractional urban cover maps that could have been used for this? My concern is that it GAIA a binary urban/non-urban map that was resampled to 1km, and not a "true" fractional cover map.

Response: thank you for your suggestion. We acknowledge that there is currently no such dataset of ISA time series information directly from remotely sensed observations. As such, generating ISA time series data through spatial aggregation from high-resolution urban extent data is a commonly adopted strategy. Moreover, it is worth to note that the GAIA data is of high quality with mean overall accuracies of above 90% across different years. Thus, the derived ISA maps from GAIA can well characterize the urban fractional information within each 1km grid. We explained this issue in our revised manuscript.

"Given that there are currently no urban fractional ISA dataset in high spatial resolution (e.g., 1km) directly obtained from satellite observations, here we adopted the commonly used strategy through spatial aggregation from high-resolution (e.g., 30m) urban extent data to derive the ISA time series data for modeling. The GAIA data record annual global urban extent (i.e., non-urban and urban) at a 30m resolution, spanning from 1985 to 2018, with overall mean accuracies above 90%. Besides, the derived historical urban extents from GAIA are temporally consistent (i.e., non-urban to urban) over past decades." (Page 4, Line 16-21)

Comment #1-3

Page 5, line 5. More information is needed on these spatial proxies, and how they were considered in the model. I suggest to add the references for each dataset used in Table 1, as well as how the spatial proxies were derived from these datasets (e.g., based on distance to the features like city centers/roads/protected areas/MODIS land cover types?).

Response: thank you for your suggestions. As suggested, we provided detailed information about these spatial proxies in our revised manuscript and the supplementary materials. These spatial proxies were mainly derived by calculating pixel-based distance to the nearest roads and locations, directly derivation from terrain (e.g., DEM and slopes), or specific constrains such as protection area. Details of these spatial proxies and their descriptions can be referred in Table 1.

"For example, some spatial proxies (e.g., land cover and protected area) were defined as specific constrains (e.g., suitable or not), while terrain and location proxies were directly calculated from the DEM and the distance to the nearest roads (or city centers), respectively." (Page 5, Line 13-16)

Table 1: The adopted spatial proxies in this study.

Spatial proxies	Description	Source
Land	Land cover	Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Dynamics (MCD12Q2) (https://doi.org/10.5067/MODIS/MCD12Q2.006)

	Protected area	The World Database on Protected Areas (WDPA) (http://wcmc.io/WDPA_Manua)
Location	Major cities	World city centers (http://ngcc.sbsm.gov.cn/article/zh/)
	Traffic	World major roads, highways, and local roads (https://www.openstreetmap.org)
Terrain	Derived from dem	Shuttle Radar Topography Mission - Digital Elevation Model (DEM) (http://earthexplorer.usgs.gov/)

Comment #1-4

Page 7, line 14: "That is, the continuous values can be divided into binary maps using different thresholds to measure the agreement between threshold-derived results and the referenced urban extent. In this way, the area under the curve (AUC) is commonly used to quantitatively evaluate the performance of derived global suitability (Hosmer et al., 2013)." Is this binary validation necessary, considering the purpose of the model was to generate fractional urban cover estimates? If so, I suggest to explain why.

Response: thank you for this question. Yes, we modeled urban fractional changes within each 1km grid, which is notably different with traditional modeling (i.e., from non-urban to urban directly). The suitability surface is one of the main components in the proposed ISA-based urban CA model, reflecting the biophysical priority for urban development. Therefore, we evaluated the performance of derived global suitability using the traditional ROC approach, which essentially is a threshold-based evaluation approach. That is, we identified those changed and persistent pixels using the threshold of 0.5 (i.e., ΔISA during 1985-2005) and then evaluated the performance of suitability surface using the indicator of AUC (*He et al., 2023*). We explained this issue in our revised manuscript.

"We evaluated the performance of derived global suitability using the receiver operating characteristic (ROC) approach, which essentially is a threshold-based evaluation (Sunde et al., 2014). That is, the continuous values can be divided into binary maps using different thresholds to measure the agreement between threshold-derived results and the referenced urban extent (i.e., identified by their increased ISA during 1985-2005 with a threshold of 0.5). In this way, the area under the curve (AUC) is used to quantitatively evaluate the performance of derived global suitability (Hosmer et al., 2013). It is worth to note that here we used the traditional ROC approach to evaluate the suitability surface, which is only one component of the adopted urban CA model in this study, despite that our modeling target is ISA instead of binary urban extent." (Page 7, Line 20-23; Page 8, Line 1-4)

Comment #1-5

Page 7, Section 3.2 (Calibration): What is the time period of the GAIA data used for the model calibration and validation? It's not clear if there was an independent calibration and validation period, or if the calibration/validation were both based on the entire 1985-2015 dataset.

Response: thank you for your question. We divided GAIA data into two temporal segments. The time series data of GAIA obtained in periods of 1985-2005 and 2005-2015 were used for calibration and validation, respectively. We rephrased the title of this subsection and clarified it in our revised manuscript.

"We calibrated the Logistic-Trend-ISA-CA model at the state level using historical urban extent time series data (i.e., GAIA) from satellite observations (1985-2005)." (page 7, line 19-20)

"Furthermore, we validated the model based on the root mean square error (RMSE) (Eq. 5) and coefficient of determination (R^2) between the modeled and observed ISAs (2005-2015) at the global scale. That is, we modeled the urban sprawl from 2005 to 2015 using the calibrated Logistic-Trend-ISA-CA model. In general, the relatively low RMSE and high R^2 suggest the calibrated urban CA model can capture urban sprawl well." (Page 8, Line 7-10)

Comment #1-6

Page 8, line 1. "Given that the GAIA data were derived from satellite observations with good quality and fine resolution, we harmonized future urban growth trends (2015-2100) from LUH2 under different SSP-RCP scenarios with the derived urban areas from GAIA in 2015." Do the GAIA data and the LUH2 data use the same definition of "urban" land? It may be another reason for the difference between the urban area extents of the two datasets in 2015.

Response: thank you for your comments. First, the urban extents from both GAIA and LUH2 database are derived from remotely sensed observations. Specifically, urban extents in LUH2 were initially estimated from spatially explicit built-up area map in 2000 from 1km DISCover dataset (*Loveland et al., 2000*). Although the definition of "urban" in LUH2 and GAIA are similar (i.e., pixel dominated by built-up areas), the GAIA data have a finer spatial resolution (i.e., 30m) and a longer temporal span (1985-2018) at an annual step, with mean overall accuracies of above 90% across different years.

"Due to the difference of adopted baseline urban extent in each product, there is a distinct gap regarding urban area in these two datasets (i.e., GAIA and LUH2). Specifically, urban extents in LUH2 were initially estimated from spatially explicit built-up data of the Data and Information System Global Land Cover (DISCover) dataset at 1km resolution, which was mainly derived from the Advanced Very High Resolution Radiometer (AVHRR) satellite observations (Loveland et al., 2000; Goldewijk, 2017). While the definitions of "urban" are similar in both products, the differences in urban areas across various regions can be attributed mainly to their spatial resolutions and mapping years. In general, the urban extent in GAIA derived from Landsat has a longer temporal span and a high accuracy, with mean overall accuracies of above 90% across different years (Gong et al., 2020a)." (Page 9, Line 14-21)

Comment #1-7

Page 13, Data availability. This data on fractional urban changes from 2015-2100 will be of much interest to researchers around the world, so I appreciate that you have made the data openly available. Considering all of the data you have generated in this study, another suggestion is that you may want to also share the development probability (Pdev) dataset, which contains the probability of urban development in each 1km grid cell(?). Using this data, readers could potentially generate their own future urban (fractional) change maps, e.g., based on national urban development/land demand scenarios.

Response: thank you for your suggestions. As suggested, we have uploaded the development probability data in FigShare with detailed explanation in our revised manuscript.

"The gridded dataset of global urban fractional change (2015-2100, 5-year interval) at 1km spatial resolution under eight future development pathways. The global urban development probability map can be downloaded from https://doi.org/10.6084/m9.figshare.20391117.v3 (He et al., 2022)." (Page 15, Line 17-19)