Thank you for the comments and suggestions. These comments were very helpful for revising and improving our paper. We have responded to the comments point by point.

Reviewer #1:

General comments:

The paper takes on the very substantial challenge of recreating historical land use for the United States. The authors are correct that outside of coarse-level reconstructions such as HYDE, that there is nothing of higher resolution that goes back to pre-settlement by European colonists. The authors pitch this methodology and dataset as the solution to that data gap. I don't think the authors are completely successful in making that argument. After stating the need for higher-resolution data, and presenting a methodology that should allow for some higher-level of spatial detail than something like HYDE, the authors inexplicably leave out any kind of spatial analysis of how well their model result performs. It's difficult when spatially explicit data on land use is hard to come by (and hence the need for this work!), but some analysis of the full-resolution data compared to a data set such as NLCD (available 2001 to 2019) could have helped establish confidence in the model to capture spatial patterns well. Even a comparison to historical county-level data would help. However, the only "spatial" analysis of the data are some very coarse regional assessments that don't provide a reader much of a feel for the model's capability for generating realistic, high-resolution spatial patterns. Validation overall is a weak point of the paper. On the one hand, I understand the difficulties in trying to "validate" results such as this, when consistent reference data is absent or scattered. However, it's not acceptable from a modeling perspective to use HYDE, NLCD, and other data to parameterize the model, and also use those data in what's labeled as "validation" of results. Given the lack of spatially explicit reference data, I have no issue with the authors doing "consistency checks" with other data sets, including missed opportunities such as county-level ag census data that could have been used to provide a better feel for the spatial patterns produced by the model. But don't try to sell it as a real "validation" of model results.
Overall, the authors continually note the "Uncertainties" associated with coarser data such as HYDE, but fail to conclusively demonstrate their results are superior in terms of those uncertainties. A major need for the paper is recognition of the differences

between source datasets, and the uncertainties it introduces into the modeling. For example, many parts of the model are parameterized by using multiple datasets that have inherent differences. Pasture, for example, is quantified at a state level by NRI, and then HYDE for older dates. Given how variable definitions are for “pasture” in the first place, it’s asking for trouble to mix and match datasets such as that. The authors do seem to make some attempts to harmonize differences in datasets, but the methodology isn’t well-defined enough to let me know if that’s really being done. In short, historical land use reconstruction is difficult because 5 different datasets may give you 5 different answers for how much “forest”, “urban”, “cropland”, or “pasture” is actually there for a given date! The spatial allocation of “change” on the landscape is also quite simplistic, based solely on probability surfaces with no stochasticity. The authors do attempt to mitigate the ‘static probability surface’ problem present for past applications such as CLUE and FORE-SCE by some simple weighting with population. But the actual allocation is fully dependent on the probability surfaces at the end of the day, and as a result, as you go back in time, you tend to see classes such as cropland and pasture become concentrated in the high-probability locations, with less fragmentation that’s there in later dates.

Finally, note I did download and look at some of the output results. For brevity I’ll keep my comments here to the “Boolean” land cover. Note that while results look reasonable at broad scales, the approach of parameterizing state-by-state does seem to cause some issues as you go back in time, as does the spatial allocation methodology. Going back in time reveals a number of obvious state and even what appear to be county boundaries, hard obvious lines where land use clearly differs on either side of a political boundary. Given the complete reliance on probability surfaces alone for the spatial allocation of change, land use looks more concentrated on the landscape for some classes going back in time. For example, on the 1850 map, cropland is concentrated in very large contiguous chunks in many areas, and very sharp and obvious political boundaries are present.

Response: Thank you for the comments and suggestions.

(1) According to your suggestions, we conducted another two data comparisons to increase the newly developed LULC data’s confidence in section 3.1. First, we did a comparison between our reconstruction with USDA county-level crops area in 1850, 1920, 1959, and 2002 (Figure R1). Second, we compared our data with NLCD at the grid level and calculate the difference (Figure R2). Please see Lines 304 to 338.

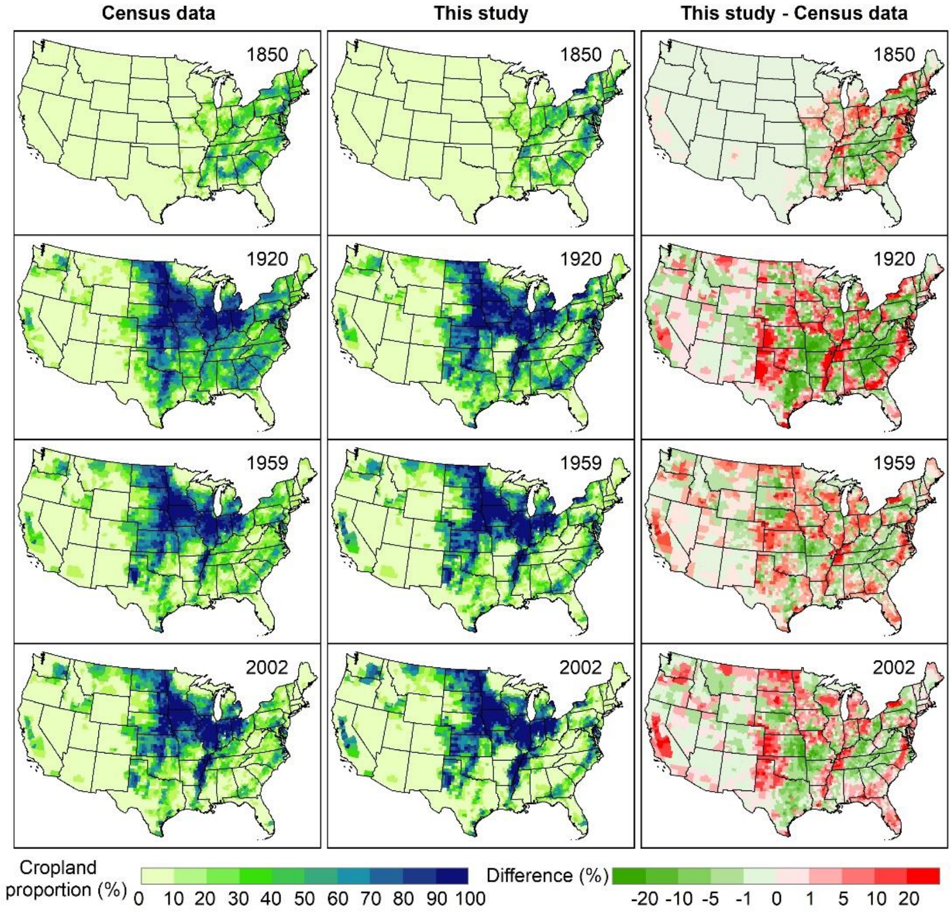


Figure R1. Spatial comparison of county-level cropland proportion between our reconstruction and census data in 1850, 1920, 1959, and 2002. First column: cropland proportion from census data; Second column: cropland proportion derived from this study; Third column: cropland proportion between this study and census data.

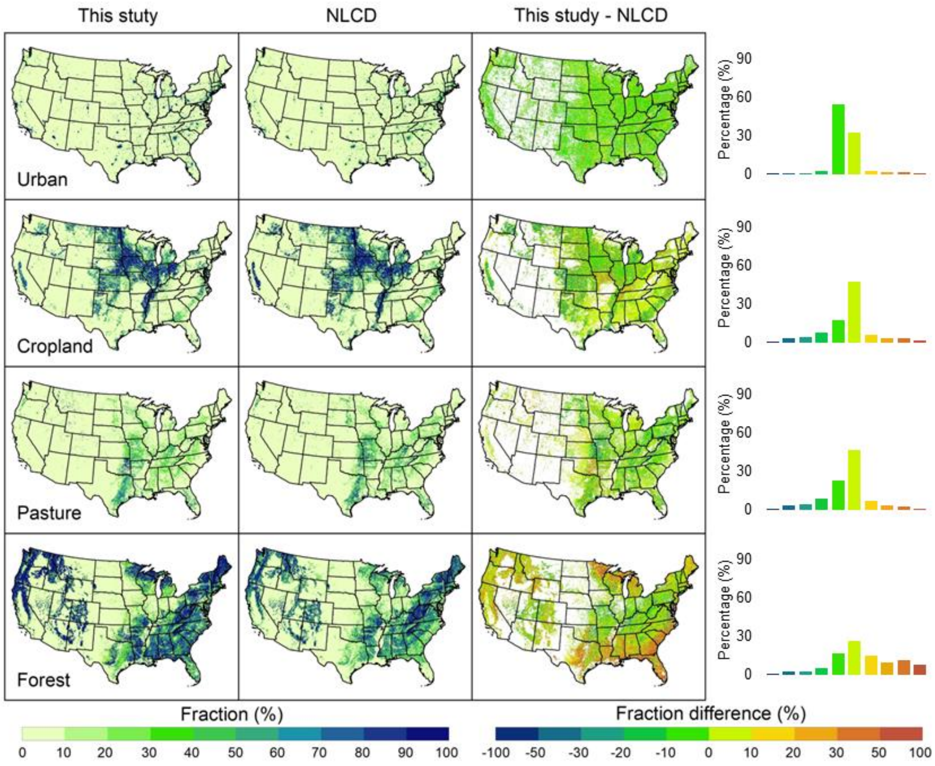


Figure R2: Spatial comparison between our reconstruction and satellite-based urban, cropland, pasture, and forest. First column: Reconstructed data in this study (average between 2001 and 2019); Second column: Satellite-based data (average between 2001 and 2019); Third column: Difference between first column and second column; Fourth column: Distributions of fraction difference between our reconstructed database and satellite-based data.

(2) As you said, the definitional differences did increase the uncertainties of LULC modeling because we had to harmonize multiple datasets for each LULC type. Thus, we compared the definitions for cropland, pasture, and forest from the multisource datasets, please see Table R1, R2, and R3. Moreover, to make readers understand the urban, cropland, pasture, and forest reconstruction process more easily, we add a table (Table 2) to introduce the LULC definitions used in this study.

Table R1: Definition of cropland in different data sources.

Data source	Definition
USDA-ERS	***Cropland*****:** Total cropland includes five components: cropland harvested, crop failure, cultivated summer fallow, cropland used only for pasture, and idle cropland (https://www.ers.usda.gov/data-products/major-land-uses/glossary/#croplandforcrops).
USDA-NRI	***Cropland*****:** A land cover/use category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and non-cultivated. Cultivated land comprises land in row crops or close-grown crops, as well as other cultivated cropland; for example, hayland or pastureland that is in a rotation with row or close-grown crops. Non-cultivated cropland includes permanent hayland and horticultural cropland.
NLCD	***Cultivated Crops*****:** areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled (https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description).
HYDE	FAO categories of "arable land and permanent crops" (Klein Goldewijk et al., 2017).

Table R2: Definition of grazing land, pasture, and rangeland in different data sources.

Data source	Definition
USDA-ERS	***Cropland pasture*****:** Cropland pasture includes acres of crops hogged or grazed but not harvested and some land used for pasture that could have been cropped without additional improvement. ***Grassland pasture and range*****:** Grassland pasture and range encompass all open land used primarily for pasture and grazing, including shrub and brush-land types of pasture, grazing land with sagebrush and scattered mesquite, and all tame and native grasses, legumes, and other forage used for pasture or grazing—regardless of ownership. ***Forest land grazed***: Forested pasture and range consisting mainly of forest, brush-grown pasture, arid woodlands, and other areas within forested areas that have grass or other forage growth. https://www.ers.usda.gov/data-products/major-land-uses/glossary/
USDA-NRI	***Pasture***: A land cover/use category of land managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. Management usually consists of cultural treatments: fertilization, weed control, reseeding, renovation, and control of grazing. For the NRI, includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock (U.S. Department of Agriculture, 2020).

	Rangeland: A broad land cover/use category on which the climax or potential plant cover is composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland (U.S. Department of Agriculture, 2020).
EPA	***Pastures*****:** Pastures are those lands that are primarily used for the production of adapted, domesticated forage plants for livestock. ***Rangelands*****:** Rangelands are those lands on which the native vegetation (climax or natural potential plant community) is predominantly grasses, grass-like plants, forbs, or shrubs suitable for grazing or browsing use. Rangelands include natural grassland, savannas, many wetlands, some deserts, tundra, and certain forb and shrub communities. https://www.epa.gov/agriculture/agricultural-pasture-rangeland-and-grazing
NLCD	***Pasture/Hay*****:** Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation. https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description
HYDE	***Grazing land*****:** Land used for mowing or grazing livestock, based on the FAO category "permanent meadows and pastures". Grazing land can be a variety of ecosystems, ranging from managed irrigated grasslands to unmanaged open savannah woodlands to semi-shrub/scrub, almost desert, lands (Klein Goldewijk et al., 2017). ***Pasture*****:** Pasture is high-intensity grazing land, or low intensity grazing lands where a conversion of the natural vegetation has occurred (Klein Goldewijk et al., 2017). ***Rangeland*****:** rangeland is low-intensity grazing land where the natural vegetation has not been converted (Goldewijk et al., 2017).

Table R3. Forest definitions from different data sources.

Data source	**Definition**
FIA	Land at least 10 percent stocked by forest trees of any size, or formerly having such tree cover, and not currently developed for non-forest uses, with a minimum area classification of 1 acre (https://www.fia.fs.fed.us/tools-data/maps/2007/descr/yfor_land.php).

NLCD	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover (https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description).
LUH2	Forest was defined using a single tree canopy cover threshold to match the global forest extent provided by the FAO FRA report (Hurtt et al., 2020).

(3) For the spatial allocation, we agree with you that the actual allocation is dependent on the probability surfaces and the landscape pattern at the end of the day. CLUE model and FORE-SCE model generate a LULC map at the predicted year by allocating the LULC demand (LULC area net change) to a LULC base map. This method works well for short-period studies because they can assume that the large-scale LULC pattern is stable. To be honest, we also tried such a spatial allocation method for generating fractional and Boolean-type data. However, the contemporary LULC pattern is not representative for the historical LULC pattern even going back to the 1940s in CONUS (Sohl et al., 2016). Thus, we need to add some modifiers (e.g., population density) to improve the LULC probability. We know it is simple by adding a population weight, but it is effective. Because the distribution of human-related LULC types (e.g., urban, crop, and pasture) was always correlated with population density in the early period. In Figure R3, we can see that the county-level population and cropland proportion show the same spatial patterns in 1850.

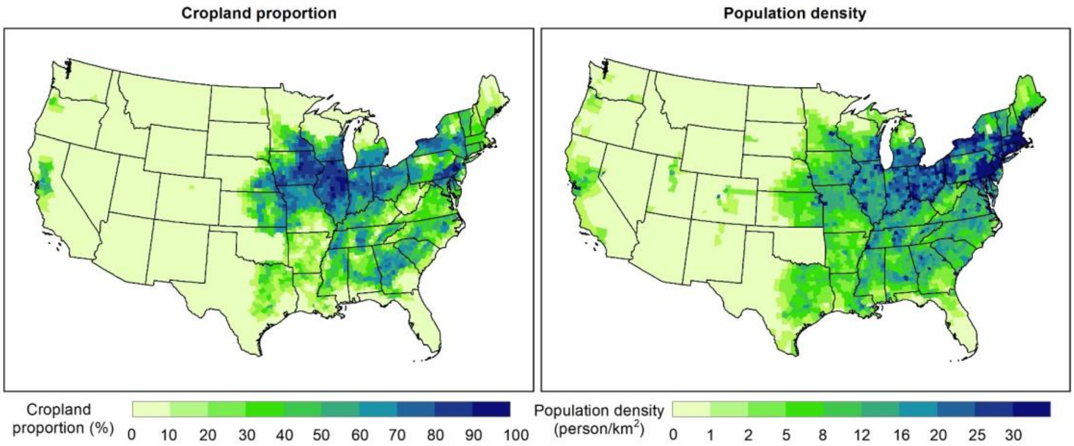


Figure R3: County-level cropland proportion (left) and population density (right) in 1850.

(4) To generate the fractional gridded LULC data, we assumed that the fraction of each LULC type at the grid level is determined by the total probability (Fuchs et al., 2013; Tian et al., 2014; West et al., 2014; He et al., 2015). It means that a grid cell (LULC type k) with a high probability will have a high fraction. Based on this principle and the state-level LULC area, we generated the fractional LULC data at 1 km x 1 km resolution and annual time scale. The detailed information for generating fractional LULC data is shown in the following steps: (1) prepare the input data: state-level historical LULC area and probability; (2) calculate the state target LULC fraction for type k and initialize an empty LULC fraction surface; (3) calculate a temporal fraction surface; (4) modify the temporal fraction, we assume that the fraction of water and barren is stable, and the sum of urban, crop, pasture, and forest fraction is lower than the maximum fraction in each grid cell; (4) add the temporal fraction data to the empty LULC fraction; (5) judge whether the unallocated LULC area is smaller than 0.01 km^2, if yes, the iteration will stop and begin to allocate another LULC type, else the unallocated area will be assigned to target fraction and return to step (3). The allocation was processed iteratively until the unallocated area was less than the threshold (0.01 km^2). The above steps will be conducted for each state, and urban, cropland, pasture, and forest fractional map in the CONUS will be output.

Based on the LULC fraction map, we generated the Boolean type LULC data at 1 km x 1 km resolution. The detailed information for is shown the following steps: (1) prepare the input data: state-level historical LULC area and LULC fraction data; (2) generate a temporal LULC map (HistB) through identifying the dominate LULC type in each grid cell and initialize an empty LULC map ($HisB_E$); (3) calculate the area difference for LULC type k between the HisB map and target area; (4) if the area difference is negative, we first sort the LULC fraction data where HisB equals to k, the top m (equals to target area) grid cells where $HisB_E$ not be assigned a value will be assigned as k, then if the available number of grid cell (type k) is less than the target area, we will sort the LULC fraction data where HisB map not equal to k, and the top n (equals to unallocated area) grid cells where $HisB_E$ not be assigned a value will be assigned as k; (5) if the area difference is positive, the grid cells where HisB data equals to k and the will be assigned k to $HisBE_E$ not be assigned a value; then we will sort the LULC fraction data where HisB data not equals to k, and the top n (equals to unallocated area) grid cells where $HisB_E$ not be assigned a value will be assigned as k. If step (4) and (5) finish, the next LULC type will begin to allocate. After the four LULC types of allocation finish, the grid cell not be assigned a type will be updated using the HisB data and LANDFIRE Biophysical Settings data.

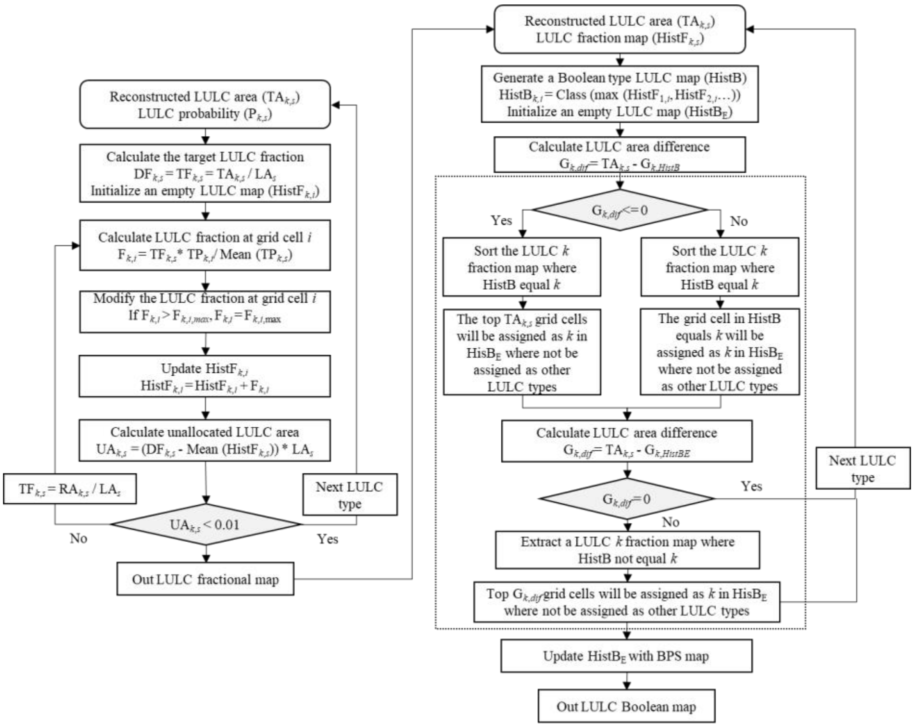


Figure R4: Workflow for generating fractional (left) and Boolean (right) type LULC data.

(5) For the Boolean type data, you proposed several suggestions as follows:

- *Cropland and pasture become concentrated in the high-probability locations, with less fragmentation that's there in later dates.*
- *Going back in time reveals a number of obvious state and even what appear to be county boundaries, hard obvious lines where land use clearly differs on either side of a political boundary.*
- *Given the complete reliance on probability surfaces alone for the spatial allocation of change, land use looks more concentrated on the landscape for some classes going back in time.*

We re-check the Boolean type LULC data and analyze the reasons for these problems. The 'political boundary' issue resulted from the following two aspects. The first is that we conduct the spatial allocation at the state level. If the area of one LULC type has a large difference between two neighboring states, there would be a 'political boundary'. The second reason is that we use county-level population density (one value in a county) to modify the LULC probability in the early period, which will result in the hardlines between neighborhood counties. The LULC '*concentration*' problems also resulted from that we apply the population density data to modify the LULC probability surface. In our revised version, we optimized the population density weight and Boolean type spatial allocation method. A detailed description of the method can be found in section 2.4.1 and 2.4.2. Figure R5 shows the comparison of LULC at the local scale in 1850.

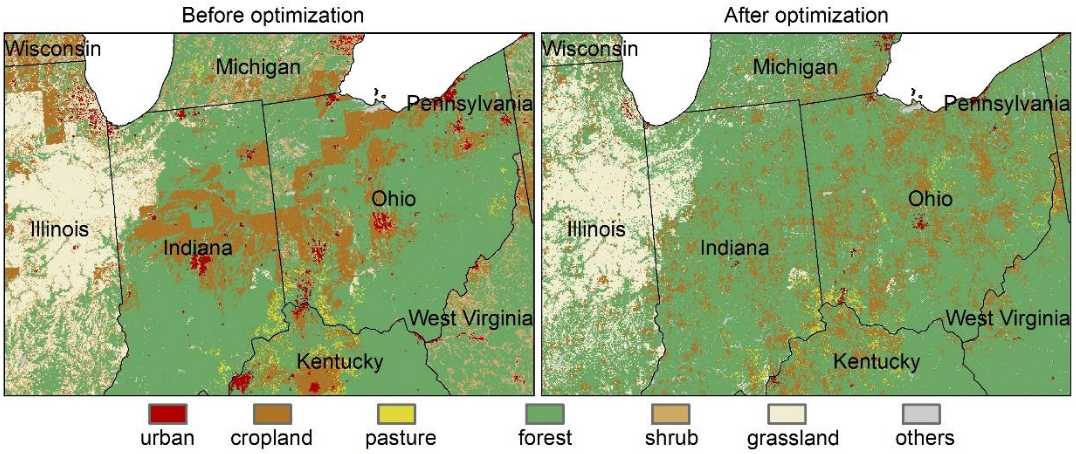


Figure R5: Comparison of Boolean type LULC map in 1850 between before and after optimization.

References:

Goldewijk, K. K., Beusen, A., Doelman, J., and Stehfest, E.: Anthropogenic land use estimates for the Holocene - HYDE 3.2, Earth Syst. Sci. Data, 9, 927-953, https://doi.org/10.5194/essd-9-927-2017, 2017.

Hurtt, G. C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Goldewijk, K. K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenoder, F., Jungclaus, J., Kaplan, J. O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6, Geosci. Model Dev., 13, 5425-5464, https://doi.org/10.5194/gmd-13-5425-2020, 2020.

Sohl, T., Reker, R., Bouchard, M., Sayler, K., Dornbierer, J., Wika, S., Quenzer, R., and Friesz, A.: Modeled historical land use and land cover for the conterminous United

States, J. Land Use Sci., 11, 476-499, https://doi.org/10.1080/1747423X.2016.1147619, 2016.

U.S. Department of Agriculture.: Summary Report: 2017 National Resources Inventory, Natural Resources Conservation Service Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa, 2020.

Specific comments:

Comment 1: Lines 28 – Would add one word…" In particular, managing agriculture and forest-related activities…"

Response: Thank you for this suggestion. We revise those sentences. Please see Line 31.

Comment 2: Line 34 – Would add words…"…arrival of Europeans, indigenous communities practiced agriculture and crop planting in the…"

Response: Thank you for this suggestion. We revise those sentences. Please see Line 36.

Comment 3: Line 36 – Would change "mainly occurred" to "initially occurred" to indicate these activities first started here, but expanded elsewhere later (as noted by the next sentences)

Response: Thank you for this suggestion. We revise those sentences. Please see Line 28.

Comment 4: Line 37 – "Driven" not "driving".

Response: Thank you for this suggestion. We revise those sentences. Please see Line 40.

Comment 5: Page 2 – Overall the paragraph at the top of page 2 could use some work. It's a rather disjointed history of US land change. For one it doesn't really talk about land change west of the Mississippi River, it's focused solely on Eastern US change. The organization is also a bit odd and disjointed.

The sentence on line 44, for example, seems like a very abrupt and odd ending to the final statement as to why a long-term land use dataset is needed. Perhaps a better organization by period (colonial, 19th century, 20th century), with a description of what occurred in each century? And perhaps a modification of the last sentence, adding "While general trends in historical US landscape change are known, we still lack a long-term dataset…"

Response: Thank you for this suggestion. We rewrite this paragraph. Please see Lines 34-52.

Comment 6: Line 55-56 – Be careful about highlighting "uncertainties" in datasets such as HYDE, as your historical landscape construction will also have substantial uncertainties. Your workflow itself uses HYDE data. There's limited spatially explicit data available from which to base a model-based landscape reconstruction, and many of the datasets you're using were also used by HYDE.

Response: Thank you for this suggestion. We revised this sentence. Please see Lines 59-60. We agree with you that the uncertainties of HYDE should not be highlighted because HYDE data is also one of the input data in our reconstruction. The historical LULC pattern in the CONUS has changed a lot compared with the contemporary LULC pattern. This is also the reason that we used the population density and human settlement extent to improve the LULC probability, even though it is a simple method.

Comment 7: Lines 87-88 – I wouldn't call the use of these other datasets "validation". It's a consistency check, not a validation, as these data sets too have uncertainties, and some are modeled just as you're modeling.

Response: Thank you for this suggestion. These data should be the input for consistency check rather than validation. We rewrite the description about the data comparison or consistency check. We rewrite the section 2.4. Please see Lines 266-275. Moreover, we also add another two data comparisons. Please see section 3.1.2 and 3.1.3 (Lines 304-338).

Comment 8: Line 90-91 – How was resampling done to get to 1-km grid cells? Is it fractional LULC within a given 1-km cell for datasets with native resolution <1 km?

Response: Thank you for this suggestion. The input data were resampled (nearest method) or aggregated to 1 km resolution. If the dataset with native resolution < 1 km, it will be fractional LULC within a given 1-km cell. For the NLCD dataset, we generated the fractional type data to 1 km for each LULC type (urban, cropland, pasture, and forest) using the “aggregate” method.

Comment 9: Section 2.2.1 – This is an extremely simplistic methodology for calculating urban land area. To start, it’s all based on one current dataset, NLCD. How was NLCD used? First of all, NLCD tends to underestimate low-density residential lands, which can bias your results. Secondly, NLCD “urban” classes also include extensive representation of road networks, which if counted as “urban”, greatly overestimates urban land. For a rural state, for example, NLCD classes not only major roads, but every small section road has a 1-pixel-wide “urban” class representing it. Unless measures were taken to account for NLCD’s underrepresentation of low-density residential lands, and to account for all the “urban” pixels that are really roads, it biases the results. The other problem is the very simplistic method for calculating land area. You’re assuming the relationship between urban land per capita and total population is constant through time. Clearly it’s not. Without accounting for that changing relationship, urban estimates can easily be biased.

Response: Thank you for this suggestion. In this study, we count the four components (Developed, Open Space; Developed, Low Density; Developed, Medium Density; Developed, High Density) of NLCD developed land as urban land. And the developed land area between 2001 and 2019 is regarded as baseline data for historical urban land area reconstruction. Though NLCD has some shortcomings, we need to choose a dataset with a clear definition and spatial explicit map, which will be helpful for historical urban land reconstruction.

In the current method, we used the population and a stable urban land per capita to estimate the long-term urban area at the state level. We agree that it is a very simplistic method and also pointed out that it overestimates the total urban land area in the early period. To solve this problem, we apply the HISDAC data to reduce the bias between 1810 and 2000, and the method has been updated in *section 2.2.1*. Before 1810, there is no available data that can be used, and we assumed that urban land has the same change rate as the total population at the state level. Please see Lines 105-122.

Section 2.2.1

In this study, we used the same definition for the developed land as NLCD for urban land. The developed land in NLCD includes four components: open space, low intensity developed land, medium intensity developed land, and high intensity developed land (Table 2). We used the NLCD developed land area during 2001–2019 as the urban land area baseline. Before 2001, we applied Historical Settlement Data Compilation for the United States (HISDAC-US) (Leyk et al., 2020; Uhl et al., 2021) as input to reconstruct the historical urban land area. The HISDAC-US built-up areas describes the built environment for most of the CONUS from 1810 to 2015 at 5-year temporal and 250 m spatial resolution using built-up property records, locations, and intensity data (Leyk and Uhl, 2018; Uhl et al., 2021). Here, we assumed that the HISDAC built-up areas data could capture the trend of urban land development. Then, the historical urban land can be estimated as follows:

$$HistUrban_{s,t} = HistUrban_{s,t+1} \times \frac{HISDAC_{s,t}}{HISDAC_{s,t+1}} \quad (1)$$

where $HistUrban_{s,t}$ and $HistUrban_{s,t+1}$ are the reconstructed urban land area of state *s* in year *t* and *t*+1; $HISDAC_{s,t}$ and $HISDAC_{s,t+1}$ are the HISDAC built-up area of state *s* in year *t* and *t*+1.

There is no census data on urban land area before 1810. Following Liu et al. (2010), we used population to estimate the urban land area by assuming that urban land expanded at the same rate as total population during 1630–1810. The urban land area of each state can be calculated as follows:

$$HistUrban_{s,t} = HistUrban_{s,t+1} \times \frac{Pop_{s,t}}{Pop_{s,t+1}} \quad (2)$$

where $HistUrban_{s,t}$ and $HistUrban_{s,t+1}$ are the reconstructed urban land area of state *s* in year *t* and *t*+1; $Pop_{s,t}$ and $Pop_{s,t+1}$ are the total population of state *s* in year *t* and *t*+1.

References:

Leyk, S. and Uhl, J. H.: HISDAC-US, historical settlement data compilation for the conterminous United States over 200 years, Sci. Data, 5, 1-14, https://doi.org/10.1038/sdata.2018.175, 2018.

Leyk, S., Uhl, J. H., Connor, D. S., Braswell, A. E., Mietkiewicz, N., Balch, J. K., and Gutmann, M.: Two centuries of settlement and urban development in the United States, Sci. Adv., 6, https://doi.org/10.1126/sciadv.aba2937, 2020.

Liu, M. and Tian, H.: China's land cover and land use change from 1700 to 2005: Estimations from high-resolution satellite data and historical archives, Global Biogeochem. Cy., 24, GB3003, https://doi.org/10.1029/2009gb003687, 2010.

Uhl, J. H., Leyk, S., McShane, C. M., Braswell, A. E., Connor, D. S., and Balk, D.: Fine-grained, spatiotemporal datasets measuring 200 years of land development in the United States, Earth Syst. Sci. Data, 13, 119-153, https://doi.org/10.5194/essd-2020-217, 2021.

Comment 10: Section 2.2.2 – You're using (at least) three different data sources to help establish cropland area. For historical land use, estimates vary widely, dependent upon methodology, data source, thematic definitions of a land use, etc. As a result, when switching from USDA-based data, for example, after 1889, and using HYDE before 1889, you'd expect an obvious break in estimated "cropland" amounts. How were those inconsistencies among historical land use datasets harmonized?

Response: Thank you for this suggestion. In the current method, we first convert cropland harvest area to planted area by assuming a stable linear relationship between these two datasets, then we calculated the cropland area by subtracting the double-cropped area from the planted area. However, these two steps will result in some uncertainties as you said in Comment 11 and 12.

To reduce these uncertainties, we decided to change the input data for historical cropland reconstruction, including the ERS national cropland harvested area (without double-cropped area), the state level CAHA-cropland harvested area (1879-2017) and HYDE cropland (1630-1879) to reconstruct the historical cropland area. Information about the updated method please see Lines 124-153 or the following description.

Section 2.2.2

The definition of cropland varies in the existing literature and datasets (Zumkehr and Campbell, 2013; Bigelow and Borchers, 2017; Goldewijk et al., 2017; Homer et al., 2020, Table R1). Cropland, defined by the U.S. Department of Agriculture (USDA) Economic Research Service (ERS), includes five components: cropland harvested, crop failure, cultivated summer fallow, cropland pasture, and idle cropland (Table 2). In this study, we only count the cropland harvested area, which includes row crops and closely sown crops, hay and silage crops, tree fruits, small fruits, berries, and tree nuts, vegetables and melons, and miscellaneous other minor crops (https://www.ers.usda.gov/data-products/major-land-uses/glossary/#cropland). USDA Census of Agriculture Historical Archive (CAHA) recorded state-level cropland harvested areas at 4 to 10 years intervals (Table 1 and Table S5), which was used for historical cropland area reconstruction between 1879 and 2017. The CAHA cropland was interpolated into annual using the linear method first. To subtract the double-cropped area, we applied the annual national cropland harvested area without double-cropped area from ERS Major Land Uses data to adjust the interpolated cropland harvested area. The adjustment can be expressed as follows:

$$HistCrop_{s,t} = \frac{Cropland\ Harvested_{s,t}^{linear}}{Cropland\ Harvested_{conus,t}^{linear}} \times Cropland\ Harvested_{conus,t}^{ERS} \quad (3)$$

where $HistCrop_{s,t}$ is the reconstructed cropland area of state s in year t; $Cropland\ Harvested_{s,t}^{linear}$ is the linearly interpolated cropland harvested area of state s in year t based on CAHA cropland harvested area; $Cropland\ Harvested_{conus,t}^{ERS}$ is the national total cropland harvested area without double-cropped area in year t. For 2018–2020, the state-level cropland area was calculated based on the state-level area weight in 2017.

For 1879–1910, there was no national-level cropland harvested area without double-cropped area. Therefore, we applied the trend of the CAHA cropland harvested area to reconstruct the historical cropland:

$$HistCrop_{s,t} = HistCrop_{s,t+1} \times \frac{CAHA\_CHA_{s,t}}{CAHA\_CHA_{s,t+1}} \quad (4)$$

where $HistCrop_{s,t}$ and $HistCrop_{s,t+1}$ are the reconstructed cropland area of state s in year t and t+1; $CAHA\_CHA_{s,t}$ and $CAHA\_CHA_{s,t+1}$ are the cropland harvested area of state s in year t and t+1.

Because there was no available cropland census data at the state level before 1879, the HYDE cropland was used. We first estimated the cropland per capita by applying the trend of HYDE cropland per capita. Then, the total cropland area can be calculated by multiplying cropland per capita and total population. The data harmonization process can be expressed as follows:

$$HistCrop_{s,t} = (HistCrop\_p_{s,t+1} \times \frac{HYDE\_Crop\_p_{s,t}}{HYDE\_Crop\_p_{s,t+1}}) \times Pop_{s,t} \quad (5)$$

where $HistCrop_{s,t}$ is the reconstructed cropland area of state s in year t; $HistCrop\_p_{s,t+1}$ is the reconstructed cropland per capita of state s in year t+1; $HYDE\_Crop\_p_{s,t}$ and $HYDE\_Crop\_p_{s,t+1}$ are HYDE cropland per capita of state s in year t and t+1.

References:

Bigelow, D. P. and Borchers, A.: Major Uses of Land in the United States 2012, U.S. Department of Agriculture, Economic Research Service, 2017.

Goldewijk, K. K., Beusen, A., Doelman, J., and Stehfest, E.: Anthropogenic land use estimates for the Holocene - HYDE 3.2, Earth Syst. Sci. Data, 9, 927-953, https://doi.org/10.5194/essd-9-927-2017, 2017.

Homer, C., Dewitz, J., Jin, S., Xian, G., Costello, C., Danielson, P., Gass, L., Funk, M., Wickham, J., Stehman, S., Auch, R., and Riitters, K.: Conterminous United States land cover change patterns 2001-2016 from the 2016 National Land Cover Database, ISPRS. J. Photogramm. Remote Sens., 162, 184-199, https://doi.org/10.1016/j.isprsjprs.2020.02.019, 2020.

Zumkehr, A. and Campbell, J. E.: Historical U.S. Cropland areas and the potential for bioenergy production on abandoned croplands, Environ. Sci. Technol., 47, 3840-3847, https://doi.org/10.1021/es3033132, 2013.

Comment 11: Paragraph starting on line 120 – You're assuming the relationship between harvested area and planted area from 1978 to 2017 is consistent decades and centuries before those data…a very dangerous assumption.

Response: Thank you for this suggestion. We agree that the relationship between cropland harvested area and the planted area is changed. Thus, we revise the reconstruction method. This step doesn't need to conduct in the new method. Please see the new method description in the response for Comment 10.

Comment 12: Line 123 – Yet another dataset, Borchers et al. 2014, was used to establish double-cropping at a regional level. Again, consistency among most of these datasets isn't great.

Response: Thank you for this suggestion. To reduce such kind of uncertainties, we revise the reconstruction method, and the subtracting work doesn't need to conduct. Please see the new method described in the response to Comment 10.

Comment 13: Line 124-125 – Another basic assumption that likely isn't true through time.

Response: Thank you for this suggestion. We revise the cropland reconstruction method, and we used the changing trend of HYDE cropland rather than national cropland per capita. Please see the new method described in the response to Comment 10.

Comment 14: Line 125-126 – Because the 1879 number was different you assumed it was incorrect? But data >1889 were "correct"? Was the reconstructed cropland area in 1879 substantially lower or higher than 1889?

Response: Thank you for this suggestion. On the one hand, there was no record for South Dakota in 1879. On the other hand, we assumed that there should not be a large difference between the cropland harvest area between 1879 and 1889. However, the cropland harvested area in South Dakota, Nebraska, and Kansas did have large differences in 1879 and 1889 (Figure R6). Thus, we thought the cropland harvested area in 1879 is not correct before. We rechecked the changes in cropland harvested area and total population (Figure R7) between 1879 and 1889, we think the cropland harvested area recorded by CAHA should be right and can be used for cropland reconstruction. So, we used the CAHA data in the revised version. The reconstructed cropland area in 1879 was not substantially lower or higher than 1889 (Figure R8).

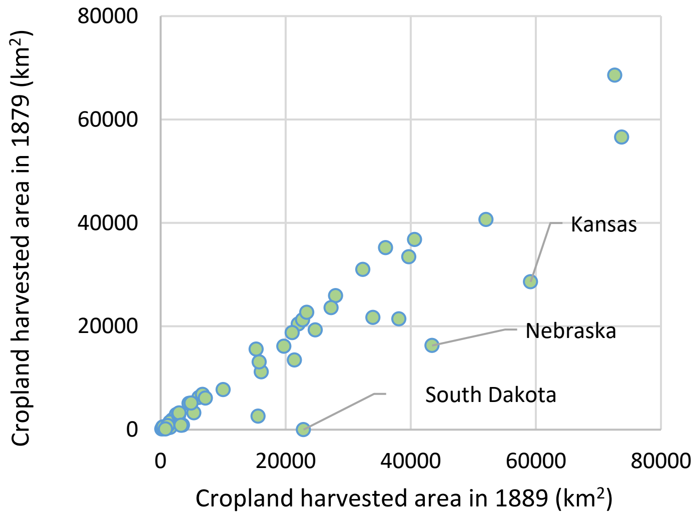


Figure R6: Comparison between cropland harvested area in 1889 and 1879.

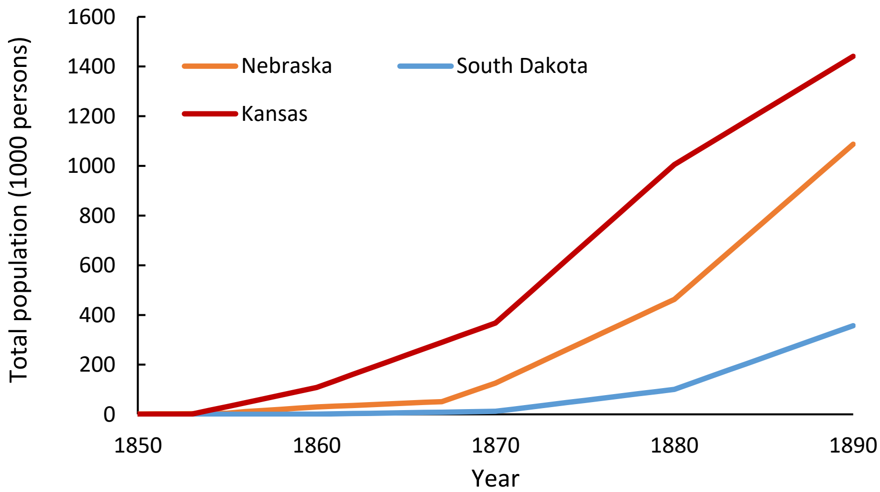


Figure R7: Changes of total population in Nebraska, Kansas, and South Dakota between 1850 and 1890.

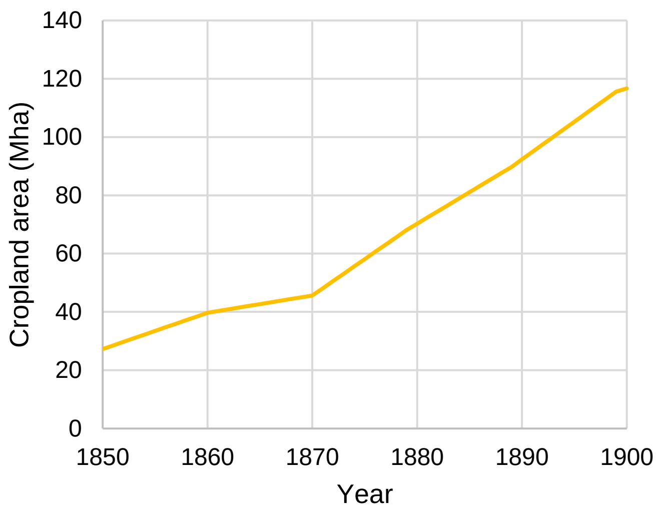


Figure R8: Changes of national total cropland area during 1850-1910.

Comment 15: Line 130-131 – Another basic assumption that likely doesn't hold region to region.

Response: Thank you for this suggestion. We change the harmonization method for integrating HYDE and reconstructed historical cropland. Please see the new method described in the response to Comment 10.

Comment 16: Line 132-133 – Again…how did you account for differences in the HYDE data, and the (mostly) USDA-based data after 1889? Is there an obvious break in cropland amount pre- and post-1889?

Response: Thank you for this suggestion. For the historical cropland reconstruction, we use the HYDE cropland area trends rather than absolute value. The harmonization method between HYDE and CAHA or reconstructed cropland area can be found in the response to Comment 10.

As our response in Comment 14, we found that cropland harvested area increased fast during 1879-1889, and this increase resulted from rapid population increase. The reconstructed data also show that cropland area in South Dakota, Nebraska, Kansa increased rapidly during 1879-1889. But there is no obvious break in cropland amount pre and post-1889 (Figure R8).

Comment 17: Line 135-136 – One of the greatest difficulties in historical landscape reconstruction is the definition of "pasture", vs. "grassland", vs. "hay" vs. "rangeland", etc. There is no one definition that's universally accepted. Your definition here states Pasture includes areas "for the production of seed or hay crops". Many definitions of "cropland" include alfalfa, hay, and other crops in "planted area" or "cultivated crop" area. For "Pasture", you're introducing yet another completely new dataset to establish pasture area, NRI. Are the definitions of "pasture" for NRI the same for NLCD, HYDE, and the US Census of Ag?

Response: Thank you for this suggestion. We summarize the definitions of grazing land, pasture, and rangeland from different sources (Table R2).

As you said, the definitions 'pasture' from NRI is not same as that in HYDE and NLCD or US Census of Ag. Therefore, it is difficult to reconstruct historical pasture area by harmonizing these datasets. We rewrite the pasture area reconstruction method, please see Lines 154-166.

In this study, we use the definition from the National Resource Inventory (NRI), in which pasture is the land that has a vegetation cover of grasses, legumes, and forbs, regardless of whether it is being grazed by livestock, planted for livestock grazing, or the production of seed or hay crops (Table 2). The NRI provides state-level pasture area with 5-year interval between 1982 and 2017, we set the pasture area as the baseline for historical reconstruction. Because there was no available pasture census data at the state level before 1982, the HYDE pasture was applied. We first estimated the pasture per capita by applying the trend of HYDE pasture per capita. Then, the total cropland area can be calculated by multiplying pasture per capita and total population. The data harmonization process can be expressed as follows:

$$HistPasture_{s,t} = (HistPasture\_p_{s,t+1} \times \frac{HYDE\_Pasture\_p_{s,t}}{HYDE\_Pasture\_p_{s,t+1}}) \times Pop_{s,t} \quad (6)$$

where $HistPasture_{s,t}$ is the reconstructed pasture area of state *s* in year *t*; $HistPasture\_p_{s,t+1}$ is pasture area per capita of state *s* in year *t*+1; $HYDE\_Pasture\_p_{s,t}$ and $HYDE\_Pasture\_p_{s,t+1}$ are the HYDE pasture per capita of state *s* in year *t* and *t*+1.

Comment 18: Line 139 – Note Wasianen and Bliss took great pains to harmonize those definitional differences across their harmonized dataset.

Response: Thank you for this suggestion. We agree that they did make great efforts to harmonize those definitional differences across multisource dataset.

Comment 19: Section 2.2.3 – Again…it's extremely simplistic to assume things such as "pasture per capita" and that that ratio is consistent over time, and space.

Response: Thank you for this suggestion. We revise the historical pasture reconstruction method. We rewrite the pasture area reconstruction method, please see Lines 154-166. The method description can also be found in the response of Comment 17.

Comment 20: Section 2.2.4 – Definitions of what is "Forest" vary greatly among data sets. You're introducing yet another data set in FIA that may have a definition of "forest" that differs from HYDE or from NLCD. How closely does the FATD data match with HYDE estimates, for example?

Response: Thank you for this suggestion. The definitional differences between FIA, NLCD, and LUH2 can be found in Table R3.

The HYDE data doesn't provide forest area estimation. So, the following figure shows the comparison between USDA-FR and NLCD, LUH2 between 2000-2020, between LUH2 and FATD in 1630. Both NLCD and LUH2 forest area are lower than USDA-FR. The forest area in Rocky Mountain states such as Nevada, Utah, New Mexico from NLCD and LUH2 is lower than that from USDA-FR. The forest area in 1630 derived from LUH2 and FATD does not match well.

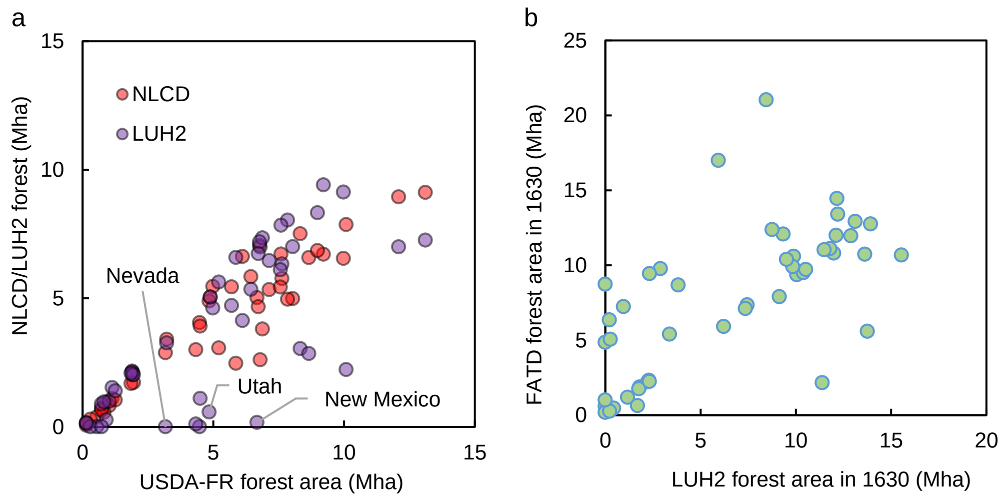


Figure R9: a. Comparison between the average forest area (2000-2020) derived from USDA-FR and NLCD, LUH2. b. Comparison between the forest area derived from FATD and LUH2 in 1630.

Comment 21: Lines 156-157 – Yeah you lost me here with what you're trying to do, needs a better explanation.

Response: Thank you for the suggestions. We rewrite the forest reconstruction method. Please see Line 176-185.

Comment 22: Section 2.2.5 – See main comments above related to how you balanced the four LULC classes.

Response: Thank you for this suggestion.

Comment 23: Line 195 – What was used to establish the “land use change boundary”? That is, what was the source of “settled area” data”?

Response: Thank you for this suggestion. We assumed that in the area where human was not settled, there was no urban land, cropland, and pasture. The human settlement boundary data were used to constrain the probability of urban, cropland, and pasture. The Exploration and Settlement maps were made by the U.S. Dept. of the Interior, Geological Survey and can be accessed at https://maps.lib.utexas.edu/maps/histus.html#exploration.html. We assumed that the LULC would not be changed as the pre-colonial era, though there were Native Indiana people.

Comment 24: I don’t mind the use of something like this to constrain the allocation of change, but do wonder about full-resolution results. Are there any hard border issues obvious in the data when change occurs at the edge of those defined boundary layers? Overall with the boundary and effect of population density, I appreciate you trying something other than assuming a static probability surface through time.

Response: Thank you for this suggestion. We check the fractional and Boolean type gridded data, there are hard border issues in some years which resulted from the county-level population application to modify the LULC probability surfaces. A simple method to generate the historical gridded population by combing the gridded population data with 1-km resolution and county-level population, which can be expressed as:

$$Pop_{i,t} = \frac{Pop_{i,t}^{county}}{Pop_{i,2000}^{county}} \times Pop_{i,2000}^{grid}$$

where, $Pop_{i,t}$ is improved population density at grid cell *i* and year *t*; $Pop_{i,2000}^{county}$ and $Pop_{i,t}^{county}$ is the county-level population density at grid cell *i* in 2000 and year *t*; $Pop_{i,2000}^{grid}$ is the gridded population density at grid cell *i* in 2000 and year *t*.

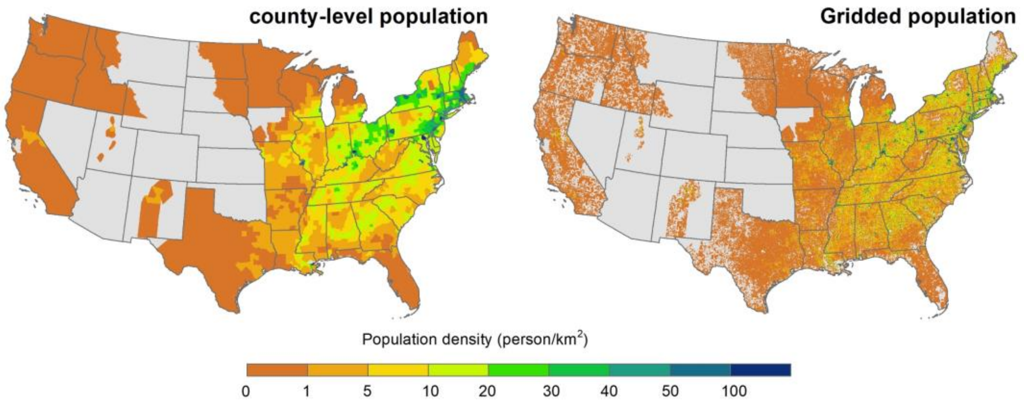


Figure R10: Comparison between county-level and gridded population density data in 1850.

Comment 25: Section 2.3.2 – There needs to be more explanation here. You've basically summarized the entire actual allocation to the pixel level in one sentence. I certainly get that higher probability areas will likely have a higher proportion of a given LULC class, but it's all deterministic and it's all based solely on the probability surface? There's no stochasticity? With such a sparse description of methodology, it's also hard to see how this simple description of the methodology ends up with the aggregate totals from the allocation stage matching the quantitative estimates you established for each of the LULC classes.

Response: Thank you for this suggestion. We rewrite the description of spatial allocation strategies for generating fractional and Boolean type LULC data and make it as detailed as possible (section 2.3.2). We also add a random item when calculating the total transition probabilities (section 2.3.1). Please see the spatial allocation method described in the response to the general comments and Figure R4.

Comment 26: As noted in the main comments, I have other concerns about the allocation strategy.

Response: Thank you for this suggestion. We rewrite the spatial allocation strategy and make it as detailed as possible. Please see the spatial allocation method described in the response to the general comments and Figure R4.

Comment 27: Section 2.4 – Comparison to other LULC datasets isn't a validation, it's a consistency check. That's particularly true when every dataset has it's own production methodologies, data sources, and thematic definitions, all of which makes even direct comparison problematic. Beyond that, you're comparing your results to some of the same datasets from which you parameterized your modeling, as noted in the overarching comments. Also note there aren't any details as to what methodologies you're actually using for "validation" in this very short, one-paragraph section.

Response: Thank you for this suggestion. We agree that the description or this step is a consistency check, rather than a data validation. Complete formal validation of model results was impractical because true, spatially explicit 'reference' data for historical LULC are difficult to obtain. In the historical LULC area reconstruction step, we assumed that the data used is reliable, which made it hard to conduct the validation. If we apply a rule to reconstruct the historical LULC area, we can use the census data to validate the accuracy of the prediction. For example, Sohl et al. (2016) used the LULC change data from the Trends project to reconstruct historical LULC proportions (demand) between 1938 and 1992, and compared the model results with census data, but such comparison still was a consistency check. Moreover, the definitional differences make it difficult to compare the newly developed dataset with other LULC products. We keep the LULC area comparison at the state level. Two new comparisons were conducted: Comparison between the newly developed cropland and USDA historical cropland area at the county level; Comparison between our reconstruction and NLCD developed land, cropland, pasture, and forest. Please see section 3.1.2 and 3.1.3 (Lines 304-338).

Comment 28: Section 3.1 – As noted previously, this isn't very useful for inferring confidence in your results, when you're using the same datasets to parameterize the model as you are to "validate" model results.

Response: Thank you for this suggestion. As our response in Comment 27, it is hard to validate the newly developed LULC data. We keep the LULC area comparison at the state level. Another two data comparisons were conducted: comparison between the newly developed cropland and USDA historical crop area at the county level; comparison between our reconstruction and NLCD developed land, cropland, pasture, and forest. Please see section 3.1.2 and 3.1.3 (Lines 304-338).

Comment 29: Line 273 (and throughout the results section) – If you're going to refer to a specific driving force of change, and, for example, point to a specific policy, you should name the policy and reference it (Immigration and Naturalization Act of 1965). While it certainly did change the nature of immigration to the country, you do give it too much focus as "the" causes of urban land increases after 1965. There's a lot more at play there than immigration policy.

Response: Thank you for this suggestion. We agree that urban land expansion is driven by multiple factors, while it is largely determined by population and economy growth. We rewrite the related sentences about urban land expansion. Please see Lines 353-359.

Comment 30: Lines 276-277 – You state "cropland area did not change significantly" from 1930 to present day. First, it's always problematic to use the term "significantly" in a journal paper, given the scientific meaning of the word. Secondly, I would argue there were "substantial" trends in agriculture after 1930, including some of those you mention (e.g., biofuel impacts).

Response: Thank you for this specific suggestion. We rewrite the related sentences, please see Line 360-361. What I want to express is that the change magnitude of the national total cropland area is not like the period of 1850-1920 (Figure R11). In fact, cropland was abandoned in the southeast US and expanded in the Great Plains.

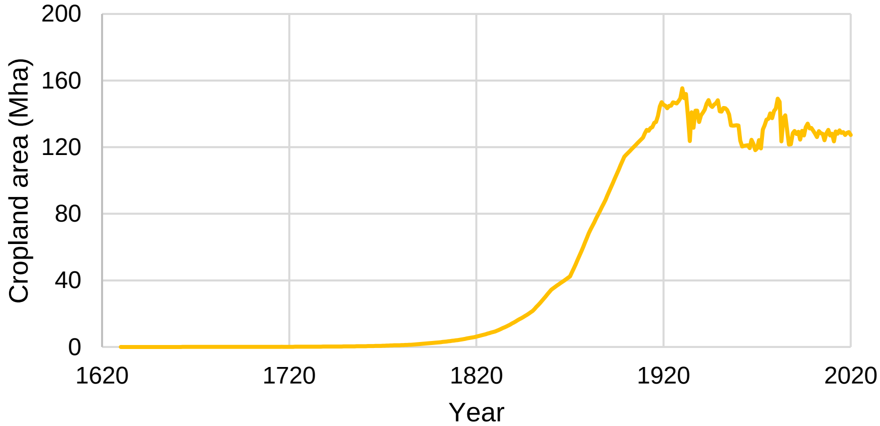


Figure R11: Changes of national total cropland area derived from the newly developed LULC dataset during 1630-2020.

Comment 31: Figure 7 – On a national-scale map figure, it's difficult to see patterns of the individual land use transitions. Perhaps it would be augmented by a complementary confusion matrix of changes or some other tabular data approach that allows you to see (and easily quantify) transition types.

Response: Thank you for this suggestion. We add a table including the information of major LULC conversions during 1630–1850, 1850–1920, 1920–2020, and 1630–2020. Please see Table 3.

Comment 32: Section 3.4 – This isn't the most effective section to me. As noted in the main comments, a major premise of the paper was to provide a "high resolution" historical landscape reconstruction for the US. Much of the "regional" information here is also discussed in the overall results above. I'd have much rather seen some real examples (and preferably validation) of landscape pattern at finer scales, given the focus on higher resolution with this paper.

Response: Thank you for this suggestion. Considering the differences in natural environmental conditions and social-economic development, land use and land cover change showed spatial heterogeneity in the CONUS during 1630–2020. The purpose of section 3.4 is to give a general description of how LULC changes among regions.

To show the improvement of newly developed LULC data, we add several figures to show LULC changes at a fine scale in the discussion section, please see Figure R12, 13, and 14.

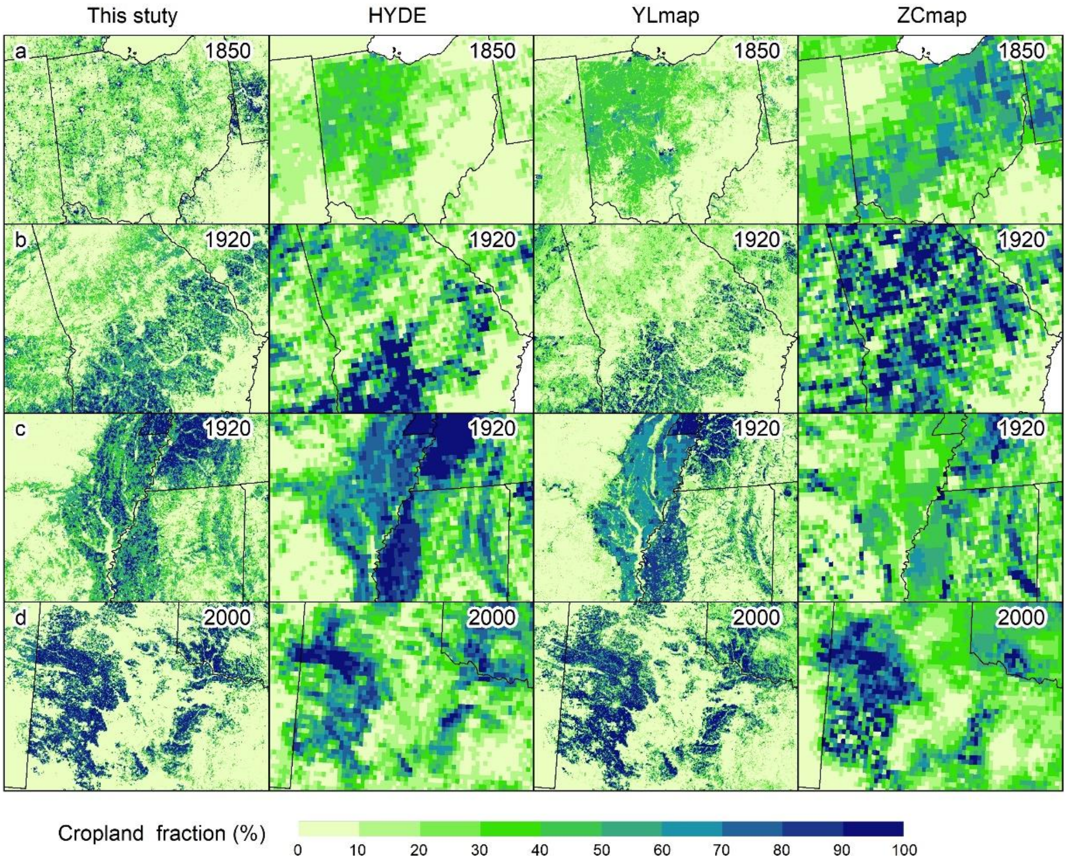


Figure R12: Visual comparison between our cropland data and the History Database of Global Environment (HYDE), Yu and Lu (2017) cropland density (YLmap), and Zumkehr and Campbell (2013) historical fractional cropland areas (ZCmap) in four different sites (a-d). The locations of image center points are as follows: a. Ohio (83.05 °W, 40.17 °N), b. Georgia (83.58 °W, 32.77 °N), c. Arkansas (90.56 °W, 34.76 °N), d. Texas (100.92 °W, 32.81°N).

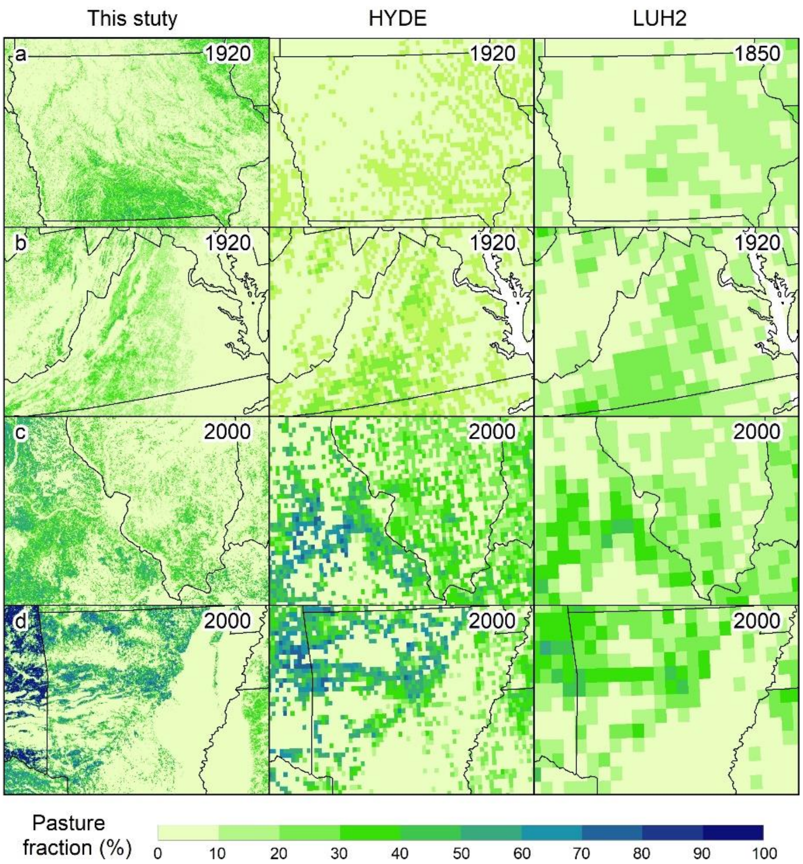


Figure R13: Visual comparison of our pasture data with History Database of Global Environment (HYDE), and Land Use Harmonization (LUH2) in four different sites (a-d). The locations of image center points are as follows: a. Iowa (93.64 °W, 42.03 °N), Virginia (78.72 °W, 37.96 °N), c. Illinois (90.07 °W, 38.68 °N), d. Arkansas (92.56 °W, 34.97 °N).

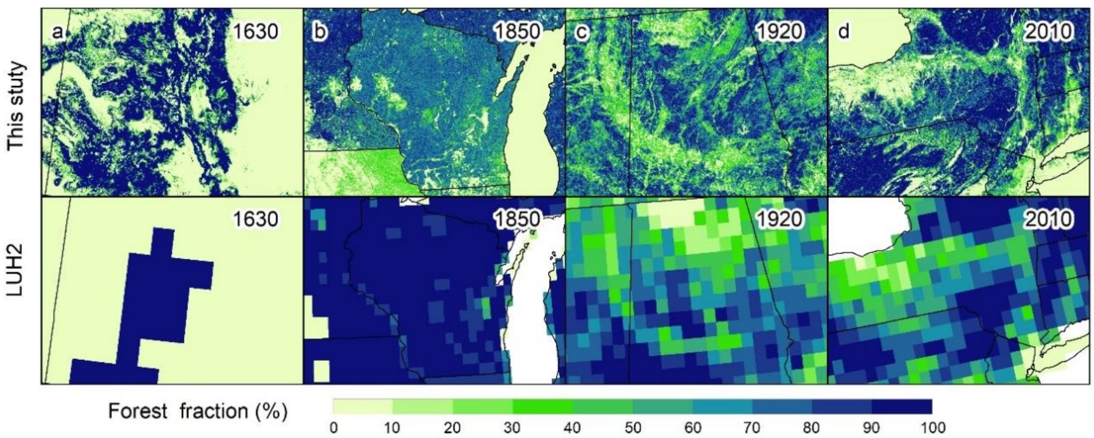


Figure R14: Visual comparison between our forest data and Land Use Harmonization (LUH2) in four different sites (a-d). The locations of image center points are as follows: a. Colorado (106.47 °W, 38.97 °N), Wisconsin (89.85 °W, 44.54 °N), c. Alabama (86.72 °W, 33.33 °N), d. New York (75.14 °W, 42.21 °N).

References:

Goldewijk, K. K., Beusen, A., Doelman, J., and Stehfest, E.: Anthropogenic land use estimates for the Holocene - HYDE 3.2, Earth Syst. Sci. Data, 9, 927-953, https://doi.org/10.5194/essd-9-927-2017, 2017.

Hurtt, G. C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Goldewijk, K. K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenoder, F., Jungclaus, J., Kaplan, J. O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6, Geosci. Model Dev., 13, 5425-5464, https://doi.org/10.5194/gmd-13-5425-2020, 2020.

Yu, Z. and Lu, C.: Historical cropland of the continental U.S. from 1850 to 2016, PANGAEA, https://doi.org/10.1594/PANGAEA.881801, 2017.

Zumkehr, A. and Campbell, J. E.: Historical U.S. Cropland areas and the potential for bioenergy production on abandoned croplands, Environ. Sci. Technol., 47, 3840-3847, https://doi.org/10.1021/es3033132, 2013.

Comment 33: Lines 338-339 – Agreed about the "per capita" approach.

Response: Thank you for this suggestion. We improve the urban land estimation method by using a changing urban land per capita. The HISDAC data is applied between 1810 and 2001 to reduce the bias in our estimation. The new method description can be found in the response to Comment 9.

Comment 34: Lines 339-341 – This doesn't serve as any kind of adequate validation or even consistency check between datasets. Showing a national-scale map and stating the patterns are "consistent" isn't valuable, and is very subjective at that scale.

Response: Thank you for this suggestion. The data validation/comparison or consistency check has been conducted in section 3.1 by comparing with NLCD data, agriculture census data, and state-level LULC area.

The national scale maps can give an overview of the spatial pattern of LULC in 1630, 1850, 1920, and 2010. We keep the national-scale map and add extra comparison figures at the fine scale to show the improvement in the newly developed LULC dataset. Please see Figure R12, R13, and R14.

Comment 35: Line 357-358 – Exactly why it's not very valuable to compare your model results to HYDE…those data were used to help establish the model parameters themselves.

Response: Thank you for this suggestion. The HYDE data was used to reconstruct historical cropland and pasture area. But not all the periods applied the HYDE data. Moreover, we used the trend of HYDE cropland/pasture per capita rather than the absolute value of LULC area. Thus, we compared the reconstructed historical LULC area and spatial pattern with HYDE.

Comment 36: Line 362 – Your product has higher spatial resolution than something like HYDE, but there's no quantitative analysis of that spatial pattern that proves the superior value of that higher native resolution.

Response: Thank you for this suggestion. We add regional scale figures to show the data improvement than the dataset with coarse resolution (Figure R12, R13, and R14). Moreover, the HYDE or LUH2 have higher cropland acreage compared to US-specific datasets, like Yu and Lu, and USDA census data. We fixed this problem and went back to 390 years ago.

Comment 37: Figure 9 – It is difficult to compare all of these datasets given the definitional differences between them, particularly for pasture and cropland.

Response: Thank you for this suggestion. We agree that it is hard to say which data is more accurate or reliable because of the definitional differences among them. But we can know whether the area of the reconstructed historical LULC dataset is in a reasonable range through data comparison. Meanwhile, the previous spatial LULC datasets are also a good reference to judge whether the reconstructed data has a reasonable spatial pattern.

Comment 38: Lines 382-383 – I'm not sure it's more "reliable", as sample-based, inventory approaches have flaws, just as satellite-based approaches have flaws. The bigger concern to me are the definitional differences, not the methodological differences.

Response: Thank you for this suggestion. We rewrite this sentence. The word 'reliable' may not be suitable to describe the FIA data, I would say it has better consistency than other forest data for long-term study. But it is hard to say which forest data is more reliable because of the differences between definitions.

NLCD and Sohl et al. (2016) data define forest as the areas dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover, higher than that in our forest definition (forest cover greater than 10%). Thus, the forest area in this study was higher than the NLCD and Sohl et al. (2016) data.

In LUH2, the biomass density (BD) map is used to identify the potential forest (BD > 2 kg C m^{-2}) and non-forest at 0.25 × 0.25-degree resolution (Hurtt et al., 2020), which underestimates the forest in Rock Mountain and Northwest. NLCD is produced by using Landsat images and a comprehensive method and provides nationwide data on land use and land cover change at a 30 m resolution (Homer et al., 2020). Spatially, it can capture the forest distribution better than LUH2. The FIA data provides critical status and trend information through a system of annual resource inventory that covers both public and private forest lands across the United States (https://www.fs.usda.gov/research/inventory/FIA), and it can provide forest trend data back to 1630.

References:

Homer, C., Dewitz, J., Jin, S., Xian, G., Costello, C., Danielson, P., Gass, L., Funk, M., Wickham, J., Stehman, S., Auch, R., and Riitters, K.: Conterminous United States land cover change patterns 2001-2016 from the 2016 National Land Cover Database, ISPRS. J. Photogramm. Remote Sens., 162, 184-199, https://doi.org/10.1016/j.isprsjprs.2020.02.019, 2020.

Hurtt, G. C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Goldewijk, K. K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenoder, F., Jungclaus, J., Kaplan, J. O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6, Geosci. Model Dev., 13, 5425-5464, https://doi.org/10.5194/gmd-13-5425-2020, 2020.

Sohl, T., Reker, R., Bouchard, M., Sayler, K., Dornbierer, J., Wika, S., Quenzer, R., and Friesz, A.: Modeled historical land use and land cover for the conterminous United

States, J. Land Use Sci., 11, 476-499, https://doi.org/10.1080/1747423X.2016.1147619, 2016.

Comment 39: Section 4.2 doesn't add a lot to the paper for me, particularly since you've already tried to explain some driving forces in the previous paragraphs of the paper. I'd much rather have the drivers woven into the story of what's happening in your results, than as a separate section.

Response: Thank you for this suggestion. The driving forces of land use and land cover change are quite complex in the United States. Though some driving forces of LULC change have been mentioned in the *Results* part, we think a comprehensive analysis of the driving forces of LULC change is still needed. We reorganize this paragraph and add more discussions. Please see Section 4.2 (Lines 510-533).

Comment 40: Lines 435-436 – I think reconstruction of historical land use is limited more by reliable, consistent historical data than methodology. Machine learning methods aren't going to be that valuable for historical reconstruction given the paucity and inconsistency of historical data for training.

Response: Thank you for this suggestion. We agree that the most important step in the historical LULC reconstruction study is to collect reliable and consistent data. The spatial allocation algorithm also impacts the reconstructed landscape pattern.

Comment 41: Section 4.3 – Somewhere in here you absolutely need to highlight the difficulties with trying to harmonize data sets with different definitions, data sources, and methodologies.

Response: Thank you for this suggestion. We rewrite the section 4.3. In this section, we add the discussion about the difficulties of harmonizing data sets with different definitions, data sources, and methodologies. Please see Section 4.3 (Lines 535-567).

Reviewer #2:

General comments:

The manuscript reconstructed land use and land cover history during 1630-2020 over the conterminous United States (CONUS). It gathered multiple sources of data including remote sensing-based land cover maps, national inventories and statistics data, meteorological fields, topographical data and others. The resulting dataset has an improved spatial resolution than other global datasets, potentially facilitating regional modeling work. However, the manuscript is not well organized. For example, in the method section, there are missing details about how various sources of input data were combined and adjusted to generate full time series of urban and crop land area. And also, the validation needs more justification on the choice of spatial scale and more discussion about what causes differences between the data from this work and other datasets. For example, this data shows a different trend in areas of urban and pasture in the past two decades compared to others. I have provided detailed comments below.

Response: Thank you for these suggestions. We revise the method for reconstructing historical urban and cropland area with more detail information, including the data used for difference period and harmonization method between different datasets. Please see the section 2.2 (Lines 105-185).

Section 2.2.1

In this study, we used the same definition for the developed land as NLCD for urban land. The developed land in NLCD includes four components: open space, low intensity developed land, medium intensity developed land, and high intensity developed land (Table 2). We used the NLCD developed land area during 2001–2019 as the urban land area baseline. Before 2001, we applied Historical Settlement Data Compilation for the United States (HISDAC-US) (Leyk et al., 2020; Uhl et al., 2021) as input to reconstruct the historical urban land area. The HISDAC-US built-up areas describes the built environment for most of the CONUS from 1810 to 2015 at 5-year temporal and 250 m spatial resolution using built-up property records, locations, and intensity data (Leyk and Uhl, 2018; Uhl et al., 2021). Here, we assumed that the HISDAC built-up areas data could capture the trend of urban land development. Then, the historical urban land can be estimated as follows:

$$HistUrban_{s,t} = HistUrban_{s,t+1} \times \frac{HISDAC_{s,t}}{HISDAC_{s,t+1}} \quad (1)$$

where $HistUrban_{s,t}$ and $HistUrban_{s,t+1}$ are the reconstructed urban land area of state *s* in year *t* and *t*+1; $HISDAC_{s,t}$ and $HISDAC_{s,t+1}$ are the HISDAC built-up area of state *s* in year *t* and *t*+1.

There is no census data on urban land area before 1810. Following Liu et al. (2010), we used population to estimate the urban land area by assuming that urban land expanded at the same rate as total population during 1630–1810. The urban land area of each state can be calculated as follows:

$$HistUrban_{s,t} = HistUrban_{s,t+1} \times \frac{Pop_{s,t}}{Pop_{s,t+1}} \quad (2)$$

where $HistUrban_{s,t}$ and $HistUrban_{s,t+1}$ are the reconstructed urban land area of state *s* in year *t* and *t*+1; $Pop_{s,t}$ and $Pop_{s,t+1}$ are the total population of state *s* in year *t* and *t*+1.

Section 2.2.2

The definition of cropland varies in the existing literature and datasets (Zumkehr and Campbell, 2013; Bigelow and Borchers, 2017; Goldewijk et al., 2017; Homer et al., 2020, Table S5). Cropland, defined by the U.S. Department of Agriculture (USDA) Economic Research Service (ERS), includes five components: cropland harvested, crop failure, cultivated summer fallow, cropland pasture, and idle cropland (Table 2). In this study, we only count the cropland harvested area, which includes row crops and closely sown crops, hay and silage crops, tree fruits, small fruits, berries, and tree nuts, vegetables and melons, and miscellaneous other minor crops (https://www.ers.usda.gov/data-products/major-land-uses/glossary/#cropland). USDA Census of Agriculture Historical Archive (CAHA) recorded state-level cropland harvested areas at 4 to 10 years intervals (Table 1 and Table S5), which was used for historical cropland area reconstruction between 1879 and 2017. The CAHA cropland was interpolated into annual using the linear method first. To subtract the double-cropped area, we applied the annual national cropland harvested area without double-cropped area from ERS Major Land Uses data to adjust the interpolated cropland harvested area. The adjustment can be expressed as follows:

$$HistCrop_{s,t} = \frac{Cropland\ Harvested_{s,t}^{linear}}{Cropland\ Harvested_{conus,t}^{linear}} \times Cropland\ Harvested_{conus,t}^{ERS} \quad (3)$$

where $HistCrop_{s,t}$ is the reconstructed cropland area of state s in year t; $Cropland\ Harvested_{s,t}^{linear}$ is the linearly interpolated cropland harvested area of state s in year t based on CAHA cropland harvested area; $Cropland\ Harvested_{conus,t}^{ERS}$ is the national total cropland harvested area without double-cropped area in year t. For 2018–2020, the state-level cropland area was calculated based on the state-level area weight in 2017.

For 1879–1910, there was no national-level cropland harvested area without double-cropped area. Therefore, we applied the trend of the CAHA cropland harvested area to reconstruct the historical cropland:

$$HistCrop_{s,t} = HistCrop_{s,t+1} \times \frac{CAHA\_CHA_{s,t}}{CAHA\_CHA_{s,t+1}} \quad (4)$$

where $HistCrop_{s,t}$ and $HistCrop_{s,t+1}$ are the reconstructed cropland area of state s in year t and t+1; $CAHA\_CHA_{s,t}$ and $CAHA\_CHA_{s,t+1}$ are the cropland harvested area of state s in year t and t+1.

Because there was no available cropland census data at the state level before 1879, the HYDE cropland was used. We first estimated the cropland per capita by applying the trend of HYDE cropland per capita. Then, the total cropland area can be calculated by multiplying cropland per capita and total population. The data harmonization process can be expressed as follows:

$$HistCrop_{s,t} = (HistCrop\_p_{s,t+1} \times \frac{HYDE\_Crop\_p_{s,t}}{HYDE\_Crop\_p_{s,t+1}}) \times Pop_{s,t} \quad (5)$$

where $HistCrop_{s,t}$ is the reconstructed cropland area of state s in year t; $HistCrop\_p_{s,t+1}$ is the reconstructed cropland per capita of state s in year t+1; $HYDE\_Crop\_p_{s,t}$ and $HYDE\_Crop\_p_{s,t+1}$ are HYDE cropland per capita of state s in year t and t+1.

For the data validation/comparison, we add the causes analysis for the differences between the datasets, please see section 3.1.1 (Lines 279-303). Considering the importance of cropland and the census data availability, we add the county level cropland area comparison between our data and USDA census data, please see section 3.1.2 (Lines 304-322). Moreover, we also compare the NLCD and our data at grid level, please see section 3.1.3 (Lines 323-338).

References:

Bigelow, D. P. and Borchers, A.: Major Uses of Land in the United States 2012, U.S. Department of Agriculture, Economic Research Service, 2017.

Goldewijk, K. K., Beusen, A., Doelman, J., and Stehfest, E.: Anthropogenic land use estimates for the Holocene - HYDE 3.2, Earth Syst. Sci. Data, 9, 927-953, https://doi.org/10.5194/essd-9-927-2017, 2017.

Homer, C., Dewitz, J., Jin, S., Xian, G., Costello, C., Danielson, P., Gass, L., Funk, M., Wickham, J., Stehman, S., Auch, R., and Riitters, K.: Conterminous United States land cover change patterns 2001-2016 from the 2016 National Land Cover Database, ISPRS. J. Photogramm. Remote Sens., 162, 184-199, https://doi.org/10.1016/j.isprsjprs.2020.02.019, 2020.

Leyk, S. and Uhl, J. H.: HISDAC-US, historical settlement data compilation for the conterminous United States over 200 years, Sci. Data, 5, 1-14, https://doi.org/10.1038/sdata.2018.175, 2018.

Leyk, S., Uhl, J. H., Connor, D. S., Braswell, A. E., Mietkiewicz, N., Balch, J. K., and Gutmann, M.: Two centuries of settlement and urban development in the United States, Sci. Adv., 6, https://doi.org/10.1126/sciadv.aba2937, 2020.

Liu, M. and Tian, H.: China's land cover and land use change from 1700 to 2005: Estimations from high-resolution satellite data and historical archives, Global Biogeochem. Cy., 24, GB3003, https://doi.org/10.1029/2009gb003687, 2010.

Uhl, J. H., Leyk, S., McShane, C. M., Braswell, A. E., Connor, D. S., and Balk, D.: Fine-grained, spatiotemporal datasets measuring 200 years of land development in the United States, Earth Syst. Sci. Data, 13, 119-153, https://doi.org/10.5194/essd-2020-217, 2021.

Zumkehr, A. and Campbell, J. E.: Historical U.S. Cropland areas and the potential for bioenergy production on abandoned croplands, Environ. Sci. Technol., 47, 3840-3847, https://doi.org/10.1021/es3033132, 2013.

Specific comments

Comment 1: P2, L55, LUH2 has a spatial resolution of 0.25-deg.

Response: Thank you for this suggestion. We revise it. Please see Line 60.

Comment 2: P2, l55, please provide references to the ‘substantial uncertainties’ statement.

Response: Thank you for this suggestion. We revise the word of "**substantial uncertainties**", and add references describing the spatial uncertainties of LULC data with coarse resolution.

References:

Yu, Z. and Lu, C.: Historical cropland expansion and abandonment in the continental U.S. during 1850 to 2016, Glob. Ecol. Biogeogr., 27, 322-333, http://doi.org/10.1111/geb.12697, 2018.

Lin, S., Zheng, J., and He, F.: Gridding cropland data reconstruction over the agricultural region of China in 1820, J. Geogr. Sci., 19, 36–48, http://doi.org/10.1007/s11442-009-0036-x, 2009.

Comment 3: P5, L95, it would be clearer to split the datasets by the purposes in your model (e.g., input vs validation). And also, there is no temporal resolution for each dataset. Apparently, some of them are not annual.

Response: Thank you for this suggestion. We revise Table 1 and only input datasets is in the Table 1. We add a new table (Table A2) to describe the data used for validation in the appendix.

Comment 4: P6, L100, please clarify if all land cover types of developed land (i.e., Developed, Open Space; Developed, Low Intensity; Developed, Medium Intensity; Developed High Intensity) were regarded as urban land.

Response: Thank you for this suggestion. We clarify the definition of urban land. In this study, the four components (i.e., open space, low intensity, medium intensity, high intensity developed land) in NLCD developed land is regarded as urban land. Please see Lines 107-109.

Comment 5: P6, L100, did you take an average of urban land area during 2001-2016 and use it as the baseline? Or you did make use of the time series of urban land areas. I wonder about the temporal variation of urban land per capita and its impacts on estimation of historical urban areas. It would be better to include this information in supplements.

Response: Thank you for this suggestion. We take an average of urban land area during 2001-2016 and use it as the baseline for urban land per capita. In fact, the real urban land per capita is not stable especially for such long-term study period.

We revise the urban land estimation method by applying the trend of HISDAC built-up areas between 1810 and 2001. The description about the method please see Lines 106-123.

Figure R1 shows the urban land per capita change derived from the newly developed urban land and HISDAC built-up areas during 1810–2010. The figure shows that the urban land per capita gradually increase over the past 200 years, which means that our previous data overestimated the urban land area in the early years.

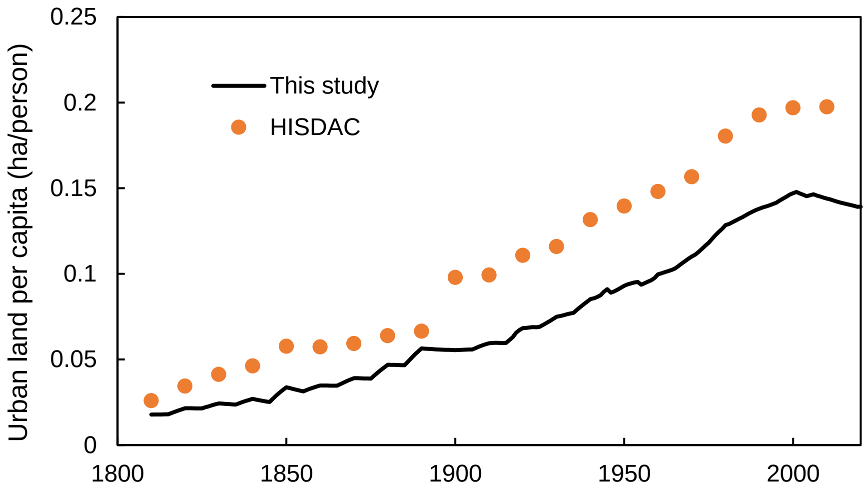


Figure R1. Urban land per capita change between 1810 and 2020. The value indicated by the orange dot is the urban land per capita derived from HISDAC built-up areas; the value indicated by the black line is the urban land per capita derived from the newly developed urban land.

Comment 6: P6, L106-108, which dataset were these criteria applied to? CPHR, CAHA, or other?

Response: Thank you for this suggestion. The cropland harvested area from CAHA is used for historical cropland reconstruction.

Comment 7: P6, L112, I could not find the CPHR dataset in Table 1. Please make sure the product name and time period is consistent between the table and manuscript.

Response: Thank you for this suggestion. The cropland planted area in Table 1 is the CPHR data. The cropland planted area was used to establish the relationship with cropland harvested area.

Referee 1 thinks that converting cropland harvested area with an unchanged linear equation is not reasonable and dangerous. So, we change the cropland reconstruction method, and the cropland planted area is not used in the new method. Please see section 2.2.2 (Lines 124-153).

Comment 8: P6, L117, 1975-2020, right? If not, please list this dataset clearly in Table 1. Please add more details about how the adjustment was done to make 'the inter-annual variation more reasonable'. For example, was this adjustment done at national scale then disaggregated to state scale?

Response: Thank you for this suggestion. The period of cropland planted area used before is 1975-2020. In the new method, the cropland planted area data is not used. In the revised method, we also conduct an adjustment to subtract the double-cropped area, and the national cropland harvested area was disaggregated to state-scale. Please see Lines 132-140.

Comment 9: P6, L125-126, what causes this difference? Due to the CAHA crop harvested area?

Response: Thank you for this suggestion. We assumed that there should be a large difference between the cropland harvest area between 1879 and 1889. However, we found that the cropland harvested area in South Dakota, Nebraska, and Kansas increased rapidly between 1879 and 1889 (Figure R2). Thus, we thought the cropland harvested area in 1879 is not correct before.

We rechecked the changes in cropland harvested area between 1879 and 1889 and total population (Figure R3) during 1850-1890. The rapidly increase of cropland area resulted from the population growth. we think the cropland harvested area should be right and can be used for cropland reconstruction.

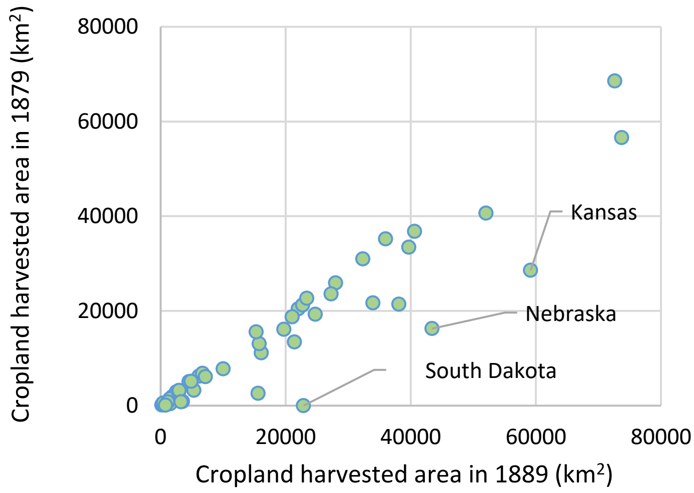


Figure R2: Comparison between cropland harvested area in 1889 and 1879

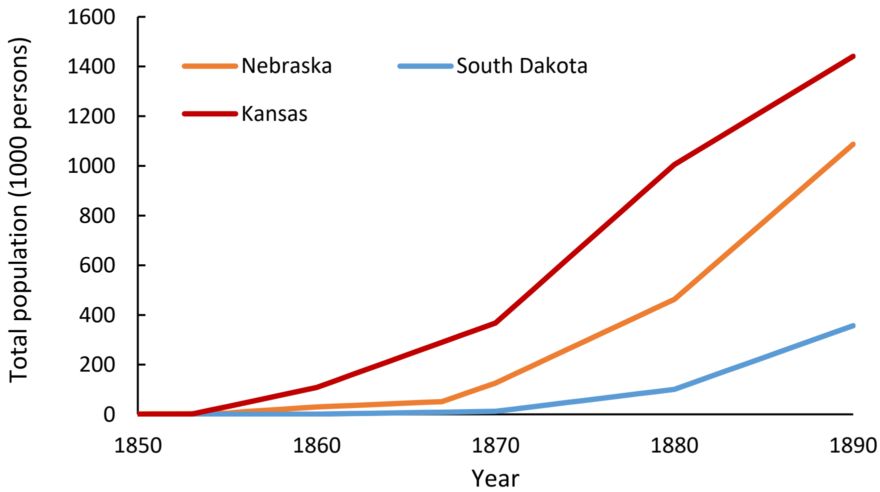


Figure R3: Total population change in Nebraska, Kansas, and South Dakota between 1850 and 1890.

Comment 10: P6, L127, please justify why the cropland per capita was calculated at national level instead of state level like the urban area per capita. This could avoid any potential confusions about the following assumption you made.

Response: Thank you for this suggestion. Considering that HYDE is reconstructed based on the country level data, so the national level cropland per capita was used before. We agree that applying the state level cropland area per capita to estimate the total cropland area should be more reasonable. In the new method, the HYDE cropland per capita for each state was used in the harmonization process. Please see Lines 145-152.

Comment 11: P7, L130-134, was there a harmonization process applied to connect cropland area during 1630-1880 derived from the HYDE and cropland area during 1889-2020 derived from the CAHA? If not, please add time-series plots of derived cropland areas that show such harmonization is not needed.

Response: Thank you for this suggestion. There was a harmonization process to connect cropland area derived from HYDE and reconstructed historical cropland area. Please see Lines 145-152.

Because there was no available cropland census data at the state level before 1879, the HYDE cropland was used. We first estimated the cropland per capita by applying the trend of HYDE cropland per capita. Then, the total cropland area can be calculated by multiplying cropland per capita and total population. The data harmonization process can be expressed as follows:

$$HistCrop_{s,t} = (HistCrop\_p_{s,t+1} \times \frac{HYDE\_Crop\_p_{s,t}}{HYDE\_Crop\_p_{s,t+1}}) \times Pop_{s,t} \quad (5)$$

where $HistCrop_{s,t}$ is the reconstructed cropland area of state *s* in year t; $HistCrop\_p_{s,t+1}$ is the reconstructed cropland per capita of state s in year t+1; $HYDE\_Crop\_p_{s,t}$ and $HYDE\_Crop\_p_{s,t+1}$ are HYDE cropland per capita of state *s* in year *t* and *t*+1.

Comment 12: P7, L141-L143, please clarify how the pasture per capita during 1630–1982 was estimated from pasture per capita at the state level (NRI data-based) in 1982 and the national level (HYDE data-based).

Response: Thank you for the suggestions. Same as the cropland area estimation, we agree that applying the state level pasture per capita to estimate the total pasture area should be more reasonable. In the new method, the HYDE cropland per capita for each state was used in the harmonization process. Please see Lines 154-166.

Because there was no available pasture census data at the state level before 1982, the HYDE pasture was applied. We first estimated the pasture per capita by applying the trend of HYDE pasture per capita. Then, the total cropland area can be calculated by multiplying pasture per capita and total population. The data harmonization process can be expressed as follows:

$$HistPasture_{s,t} = (HistPasture\_p_{s,t+1} \times \frac{HYDE\_Pasture\_p_{s,t}}{HYDE\_Pasture\_p_{s,t+1}}) \times Pop_{s,t} \quad (6)$$

where $HistPasture_{s,t}$ is the reconstructed pasture area of state *s* in year *t*; $HistPasture\_p_{s,t+1}$ is pasture area per capita of state *s* in year *t*+1; $HYDE\_Pasture\_p_{s,t}$ and $HYDE\_Pasture\_p_{s,t+1}$ are the HYDE pasture per capita of state *s* in year *t* and *t*+1.

Comment 13: P7, L157, "... then multiplied the forest area from USDA-FR to generate …". What is the time period of USDA-FR forest area used here? 1630?

Response: Thank you for this suggestion. We revise it. …then multiplied the forest area from USDA-FR in 1630.

Comment 14: P8, L170, why is there no scaling factor for TA_t_r (s) < TLA(s) ? How was the difference/residual between TA_t_r (s) and TLA(s) dealt in your following analysis? And also, what is the source of the state's total land area (TLA)?

Response: Thank you for this suggestion. The purpose of this section is to check whether the total area of urban, cropland, pasture, and forest is larger than the state land area. If the area is lower than the state land area, we will not modify the reconstructed area of each LULC class. Thus, there is no scaling factor for TA_t_r (s) < TLA(s). We don't do consider the difference/residual between TA_t_r (s) and TLA(s) dealt in the following analysis. In the updated version, we check the reconstructed area of each LULC class, the total area of urban, cropland, pasture, and forest at each state and each year stratify the condition "TA_t_r (s) < TLA(s)", so we remove this section.

For the state's total land area, we derive the area information from state boundary file. The file can be download in the following links:

https://www.nass.usda.gov/Publications/AgCensus/2017/index.php#highlights

Comment 15: P9, L182-184, please add references to how ANN can be used to solve the nonlinear geographical problems.

Response: Thank you for this suggestion. We add related references. Please see Lines 212-213.

Comment 16: P9, L184-185, please add more details about how land use probability was generated from ANN and NLCD. And also, NLCD is supposed to be an independent variable used in the modeling, right? However, NLCD is a land cover data, how can it be useful for modeling of land use probability? Please keep in mind that land use and land cover are usually used interchangeably but are actually different terms. If you regard them as the same terms, why do you refer to it as land use probability instead of land use and land cover probability?

Response: Thank you for this suggestion. In this study, we used the ANN tool in Future Land Use Simulation (FLUS) software to estimate the probability of occurrence. The FLUS model is a land-use change simulation model that combines Cell Automata (CA) model and artificial neural networks (ANN) (Liu et al., 2017). The independent variables for the ANN model include elevation, slope, annual mean temperature, annual precipitation, annual maximum temperature (July), annual minimum temperature (January), crop productivity index, population density, distance to the city, distance to the road, distance to the railway, distance to the river, soil organic carbon, soil sand, soil clay. The purpose of ANN training is to establish the relationship between each LUCC type and the independent variables, and the NLCD Boolean type will be the dependent variable.

We agree that land use and land cover are usually used interchangeably but are different terms. In this study, we regard them as the same terms change the 'land use probability' as 'LULC probability'.

References:

Liu, X., Liang, X., Li, X., Xu, X., Ou, J., Chen, Y., Li, S., Wang, S., and Pei, F.: A future land use simulation model (FLUS) for simulating multiple land use scenarios by coupling human and natural effects, Landsc. Urban Plan., 168, 94-116, https://doi.org/10.1016/j.landurbplan.2017.09.019, 2017.

Comment 17: P9, L200, what are the difference between ES_weight_t and SE_weight_t in Eq. 4 and 6.

Response: Thank you for this suggestion. We revise it. Eq.4 should be SE_weight_t.

Comment 18: P9, L200, what are the values of t1 and t0 in Eq. 7? Are they the starting and ending year of each subperiod?

Response: Thank you for this suggestion. Yes, t0 and t1 are the starting and ending year of each subperiod.

Comment 19: P10, L216, what does 'Boolean type' mean? Categorical type like NLCD that each grid (i.e, 30 m) has a single land use and land cover type?
Response: Thank you for this suggestion. Yes, categorical type.

Comment 20: P10, L217-218, please elaborate more on "the total number of potential pixels or the land use demand was determined based on the reconstruction results in Section 2.2. Then, the area difference of land use type k between the target and current map was calculated." The resulting data from section 2.2 is the state level total area of urban, crop, pasture and forest, right? So, such 'area difference' is at the state level, right?
Response: Thank you for this suggestion. We implement the spatial allocation algorithm at state level, so the resulting data from section 2.2 is the state level total area of urban, crop, pasture and forest and the 'area difference' is also at the state level. We rewrite the spatial allocation process for both fractional LULC type and category type, please see Lines 235-266.

Comment 21: P10, L228-236, the LUH2 used for validation, but it was not mentioned in section 2.1 and Table 1.
Response: Thank you for this suggestion. We revised the material and methods section and add the description of LUH2. Please see Table A2.

Comment 22: P10 L229, please justify why the validation against NLCD was at state-level. As you highlighted that your land use data is at 1 km, a finer spatial resolution than most other data, so the validation at 1 km will be more informative about the value of this dataset. A good agreement on state-level total land use area does not necessarily indicate the spatial allocation of total area to 1 km is good as well.
Response: Thank you for this suggestion. The lack of actual spatial explicit reference data made a complete formal validation impractical. Though the LULC definitions in this study are different from other LULC datasets, data comparison is a way to access the accuracy of the reconstructed LULC area and spatial pattern. Thus, we conducted

three data comparisons to increase the confidence of the newly developed LULC datasets. First, the state-level LULC area derived from the multisource datasets was used for comparison. Considering the differences in the cover period of multiple LULC datasets, we derived the average state-level statistics area for urban, cropland, pasture, and forest from 2000 to 2020 for comparison. Second, we collected the USDA county-level cropland area between 1840 and 2012 and compared the cropland proportion with that derived from our data in four selected years (1850, 1920, 1960, and 2002). Third, we compared urban, cropland, pasture, and forest from the newly developed LULC dataset with the NLCD during 2001–2019 at the grid level. Please see Section 3.1 (Lines 278-338).

Section 3.1.2

An accurate cropland map is quite critical for historical LULC reconstruction. We compared our data with county-level census data to assess the accuracy. This study's spatial pattern of cropland proportion (i.e., cropland area/county area) is close to the census data in 1850, 1920, 1959, and 2002 (Figure R5). In 1850, both the newly developed cropland and census data showed high cropland density in the BlackBelt, New England, and the North Central. In contrast, our data was higher in North Central, the east of Virginia and North Carolina, and the south of Georgia (Figure R5). Cropland derived from this study was higher than the census data in the Atlantic coast, the Mississippi Alluvial Plain, the northwest of Texas, the west of Oklahoma, and California in 1920, 1959, and 2002. However, the cropland proportion in the Appalachian Mountains and the south of the Great Plains was lower than the census data (Figure R5). This underestimation may result from the low cropland fraction in satellite data because it is difficult for satellite data to identify the small area cropland patch in the mountain region and classify the pasture or grassland with cropland in the south of the Great Plains. Moreover, both datasets showed the cropland expansion in the North Central, the Great Plains, the Mississippi Alluvial Plain, and California between 1850 and 2002. The cropland abandonment can also be found in the Appalachian Mountains between 1920 and 2002. The statistical comparison also shows that our data fits well with the census data in 1920 (R^2 = 0.68), 1960 (R^2 = 0.89), and (R^2 = 0.91) (Figure A2). Overall, the newly developed cropland has a relatively accurate spatial pattern and proportion.

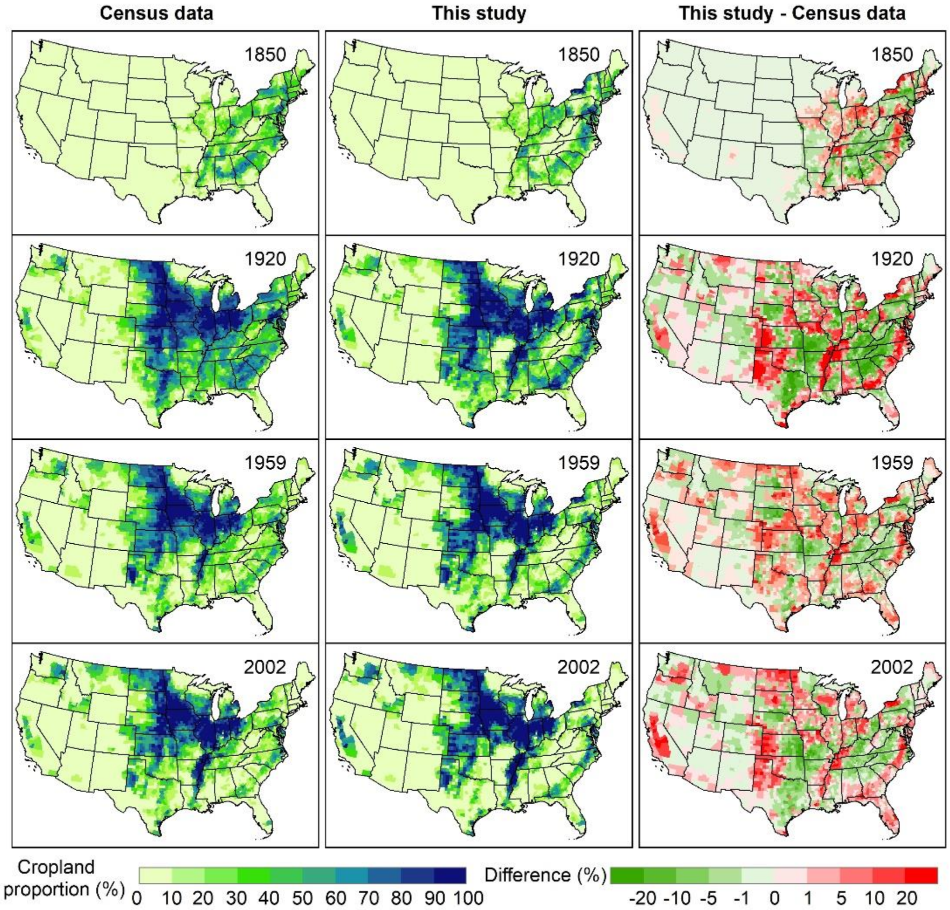


Figure R5. Spatial comparison of county-level cropland proportion between our reconstruction and census data in 1850, 1920, 1959, and 2002. First column: cropland proportion from census data; Second column: cropland proportion derived from this study; Third column: cropland proportion between this study and census data.

Section 3.1.3

The spatial patterns of urban, cropland, pasture, and forest in this study are close to the satellite-based data from NLCD, and most grid cells have a relatively small difference between 2001 and 2019 (Figure R6). Our results have a higher urban land fraction in the NLCD low urban density area, but the difference in 87% of urban grids is smaller than 10%. Cropland with a positive difference is mainly distributed in the Northeast, Alabama, and Missouri, in which 65.95% of grids have slight differences with less than 10% (Figure R6). 37.19% of grids have negative difference values and are mainly located in states with high cropland proportions. Moreover, most states in our data have a lower pasture fraction than NLCD data except in Oklahoma, Arkansas, Texas, and Georgia, and the grid cells with negative differences account for 39.82%. The reconstructed forest shows a higher density than NLCD in the South, Pacific coast, and

Great Lakes. It underestimates the forest fraction in the central states, such as Missouri, Kentucky, and Ohio. There are 58.80% grids whose differences are relatively small and with a range from -10% to 20% (Figure R6).

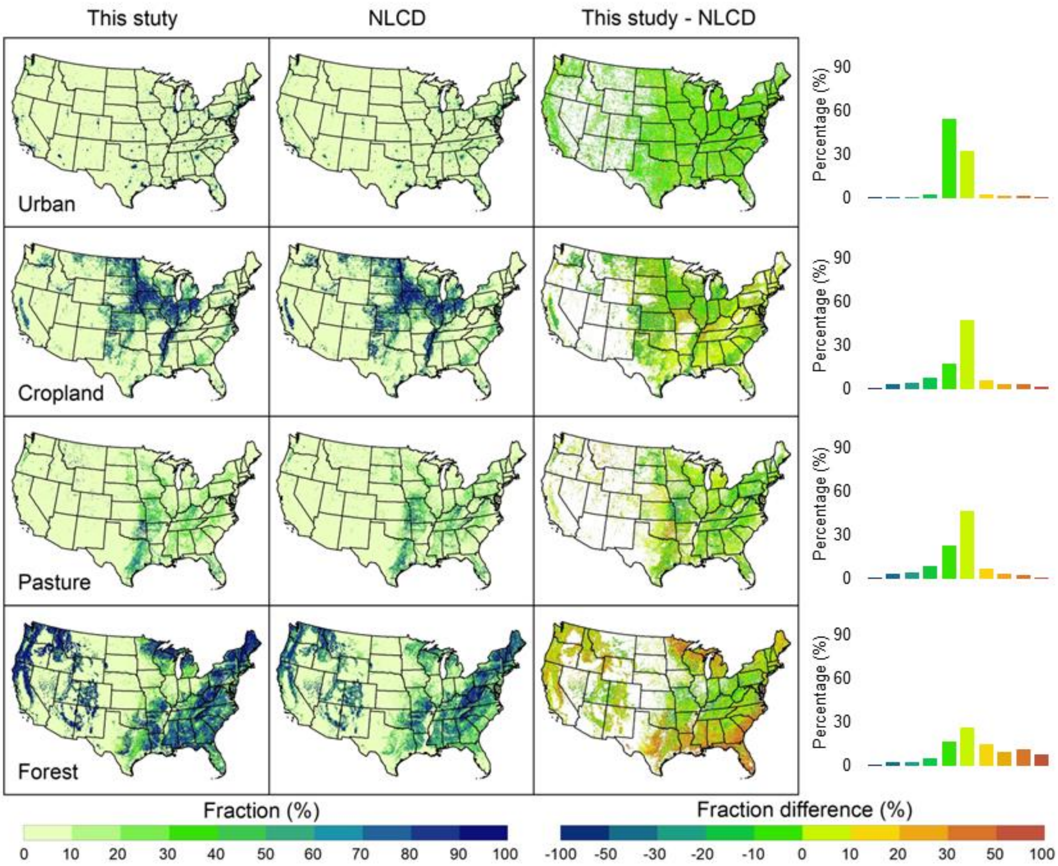


Figure R6: Spatial comparison between our reconstruction and satellite-based urban, cropland, pasture, and forest. First column: Reconstructed data in this study (average between 2001 and 2019); Second column: Satellite-based data (average between 2001 and 2019); Third column: Difference between first column and second column; Fourth column: Distributions of fraction difference between our reconstructed database and satellite-based data.

Comment 23: P11, Figure 4. Such comparisons to different datasets are very important and informative. However, I would suggest more discussion on the 'outlier' states in figure 4a and 4b. For example, please dig into which states your estimates of urban land area is lower than HISDAC? And what are the potential causes?

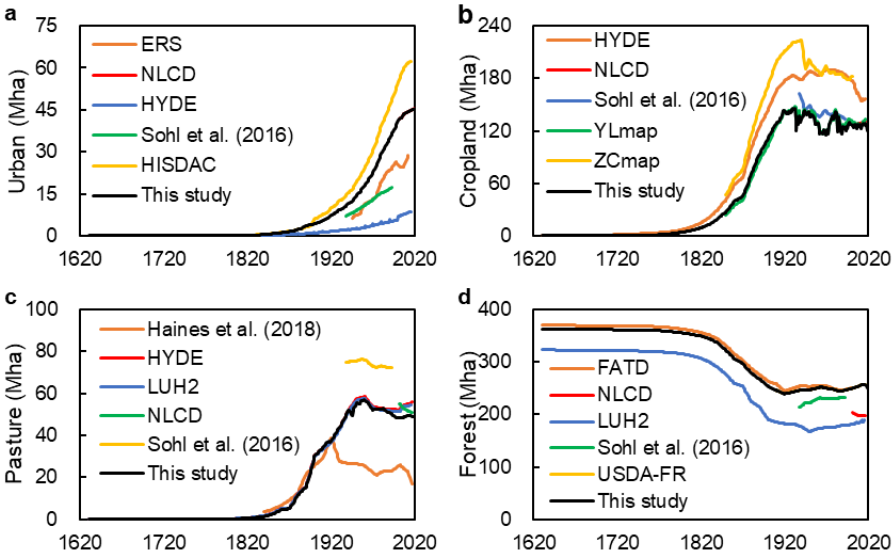
Response: Thank you for this suggestion. We revised this section and added more analysis about the differences between multiple datasets, please see Lines 279-296.

Comment 24: P14, L290-L300, is the transition in figure 7 the gross transition or net transition? Please clarify this somewhere because their magnitude and impacts on climate and carbon modeling are quite different. For example, 30% deforestation and 30% reforestation have zero transition on forest, but the biophysical effects could not be ignored.

Response: Thank you for this suggestion. We agree that the effects of LULC gross transition and net transition are quite different. Figure 7 shows the LULC net transition, that is the LULC difference in 1630, 1850, 1920 and 2020.

Comment 25: P17, Figure 9d, the black line stops at near 1920.

Response: Thank you for this suggestion. We revise the Figure 9.



Revised Figure 9: Comparison with other datasets for the conterminous United States: urban land (a); cropland (b); pasture (c); forest (d). NLCD: National Land Cover Database; HYDE: History Database of the Global Environment; HISDAC: Historical Settlement Data Compilation; ERS: Economic Research Service; YLmap: Yu and Lu (2017) cropland density; ZCmap: Zumkehr and Campbell (2013) historical fractional cropland areas; LUH2: Land Use Harmonization; FATD: Forest Area Trend Data; USDA-FR: USDA Forest Resources of the United States of 2017.

References:

Yu, Z. and Lu, C.: Historical cropland of the continental U.S. from 1850 to 2016, PANGAEA, https://doi.org/10.1594/PANGAEA.881801, 2017.

Zumkehr, A. and Campbell, J. E.: Historical U.S. Cropland areas and the potential for bioenergy production on abandoned croplands, Environ. Sci. Technol., 47, 3840-3847, https://doi.org/10.1021/es3033132, 2013.

Comment 26: P17, Figure 9a and 9c, even though NLCD is the input of urban land area to your method, there is a difference in temporal trend in urban area between NLCD and your dataset. Please discuss more about what assumptions cause such trend difference, and how it affects the reconstruction before the 2000s. Same discussion is needed for the pasture as the trend is even opposite.

Response: Thank you for this suggestion. We estimated the historical urban land area by multiplying the urban land per capita (average between 2001 and 2016) and state total population. The area difference between NLCD and our estimation was induced by the increase rate difference between urban land and total population. In the new method, the NLCD developed land area during 2001-2019 was set as the baseline. Considering the possible underestimation as you said in Comment 5, we revise the urban land estimation method by applying the HISDAC built-up area between 1810 and 2001. The new estimation method can be found in the response of Comment 5.

For the pasture, we compared the state level NRI and NLCD data. The definitions of pasture in NRI and NLCD are different. In NLCD, pasture/hay areas is land of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. But pasture includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether it is being grazed by livestock in NRI.

Comment 27: P20, L382-383, please explain why inventory-based data is more reliable than the satellite-based forest (NLCD) and biomass density-based forest (LUH2). Forests could have different definitions by various sources, and forest areas are subject to the definition, thus I could see which definition/data source is more reliable than others.

Response: Thank you for this suggestion. Exactly, it’s hard to say which forest data is more reliable because of the differences between forest definitions (Please see Table R1). In LUH2, the biomass density (BD) map is used to identify the potential forest

(BD > 2 kg C m^{-2}) and non-forest at 0.25° × 0.25° resolution (Hurtt et al., 2020), which underestimates the forest in the Rocky Mountain region and Northwest. NLCD is produced by using Landsat images and a comprehensive method and provides nationwide data on land cover and land cover change at a 30 m resolution. So, it can provide a more accurate spatial pattern than the LUH2. The FIA data provides critical status and trend information through a system of annual resource inventory that covers both public and private forest lands across the United States (https://www.fs.usda.gov/research/inventory/FIA), and it can provide a forest trend data back to 1630. Thus, we think that the forest area from FIA is more credible and consistent for long-term LULC change study.

Table R1. Forest definitions from different data sources.

Data source	Definition
FIA	Land at least 10 percent stocked by forest trees of any size, or formerly having such tree cover, and not currently developed for non-forest uses, with a minimum area classification of 1 acre (https://www.fia.fs.fed.us/tools-data/maps/2007/descr/yfor_land.php).
NLCD	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover (https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description).
LUH2	Forest was defined using a single tree canopy cover threshold to match the global forest extent provided by the FAO FRA report (Hurtt et al., 2020).

References:

Hurtt, G. C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Goldewijk, K. K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenoder, F., Jungclaus, J., Kaplan, J. O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6, Geosci. Model Dev., 13, 5425-5464, https://doi.org/10.5194/gmd-13-5425-2020, 2020.

Reviewer #3:

General comments:

This manuscript describes the development and details of a land-use dataset for the United States for the years 1630-2020. The dataset differs from other land-use datasets in that it is a high-resolution product, for almost 400 years of the historical period. The dataset combines multiple different input datasets, for different time-periods, and in different formats/spatial resolutions and reconstructs the historical areas of cropland, pasture, urban land, and forests annually at 1km x 1km spatial resolution, for the CONUS. The results show expansion of cropland and urban areas, with associated losses of natural vegetation. Comparison with other datasets show many areas of qualitative agreement, with some interesting differences for some time periods and land-use types.

Overall, the manuscript is mostly well-written and organized. It includes some useful information about the dataset development process, and an analysis of the resulting products. The dataset will be useful to modelers working in the areas of climate and ecosystems to better understand the high-resolution impacts of LCLUC in the CONUS over a long historical period. A few areas for improvement include:

Specific comments:

Comment 1: Although other alternative datasets are mentioned and compared with the new dataset, it would be helpful to know what advantages those other datasets might have (if any) over the new dataset (e.g. for HYDE an even longer time period is used, and for some datasets there could be additional data layers beyond the ones provided in this dataset, etc).

Response: Thank you for this suggestion. We add the related discussion in section 4.3, please see Lines 558-567.

The newly developed LULC dataset reconstructed the LULC history with more LULC types than ZCmap and YLmap and has higher spatial resolution than HYDE and LUH2. Our LULC data emphasizes the accuracy of area change resulting from LULC conversion rather than the changes in LULC structure or attributes. For example, forest management (e.g., wood harvest and thinning) results in the forest cover decreases and ecosystem function change, but the LULC type is unchanged. HYDE and LUH2 not only have a more extended cover period, but also provide more sub-types and LULC attributes. HYDE classified cropland into rain-fed rice, irrigated rice, rain-fed other crops, and irrigated other crops (Goldewijk et al., 2017). LUH2 divides cropland into C3 crops and C4 crops and includes the wood harvest (traditional fuelwood, commercial biofuels, and industrial roundwood) and primary/secondary forest age (Hurtt et al., 2020). In the future, the LULC sub-types (e.g., tree species, crop types) and attributes (e.g., forest age, management intensity) through collecting from agricultural census data and forest inventory data can be incorporated into our dataset (Thompson et al., 2013; Chen et al., 2017; Crossley et al., 2021).

References:

Chen, G., Pan, S., Hayes, D. J., and Tian, H.: Spatial and temporal patterns of plantation forests in the United States since the 1930s: an annual and gridded data set for regional Earth system modelling, Earth Syst. Sci. Data, 9, 545-556, https://doi.org/10.5194/essd-9-545-2017, 2017.

Crossley, M. S., Burke, K. D., Schoville, S. D., and Radeloff, V. C.: Recent collapse of crop belts and declining diversity of US agriculture since 1840, Glob. Change Biol., 27, 151-164, https://doi.org/10.1111/gcb.15396, 2021.

Goldewijk, K. K., Beusen, A., Doelman, J., and Stehfest, E.: Anthropogenic land use estimates for the Holocene - HYDE 3.2, Earth Syst. Sci. Data, 9, 927-953, https://doi.org/10.5194/essd-9-927-2017, 2017.

Hurtt, G. C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Goldewijk, K. K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenoder, F., Jungclaus, J., Kaplan, J. O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6, Geosci. Model Dev., 13, 5425-5464, https://doi.org/10.5194/gmd-13-5425-2020, 2020.

Thompson, J. R., Carpenter, D. N., Cogbill, C. V., and Foster, D. R.: Four Centuries of Change in Northeastern United States Forests, Plos One, 8, e72540, https://doi.org/10.1371/journal.pone.0072540, 2013.

Comment 2: There are different versions of HYDE3.2 – it would be good to know which one was used in this manuscript.

Response: Thank you for this suggestion. The HYDE3.2 baseline version was used, and we add the information in the Table 1.

Comment 3: Does the pasture category in the dataset include natural grasslands, as well as managed grasslands and rangelands?

Response: Thank you for this suggestion. In this study, pasture is defined as a land cover/use category of land managed primarily for the production of introduced forage plants for livestock grazing, consistent with the National Resource Inventory. So, it doesn't include natural grasslands and rangelands.

Comment 4: I also had a bit of confusion about the forest category in the dataset – is it primarily about land that is being used as a forest (regardless of the numbers or ages of trees)? Or is it based more on forest land cover? This distinction between land use and land cover could be discussed a bit more to help with this. There are several places in the manuscript where the authors state that forest area decreased due to wood harvest or fuelwood extraction, but if that did not result in a conversion to another land-use type, then the forest area would not be changed (even if the land cover changed).

Response: Thank you for this suggestion. In this study, we use the forest definition from FIA. Forest is the land at least 10 percent stocked by forest trees of any size, or formerly having such tree cover, with a minimum area classification of 1 acre (https://www.fia.fs.fed.us/tools-data/maps/2007/descr/yfor_land.php). The newly developed forest dataset doesn't include the tree numbers or age information, and it is land used as forest.

Moreover, we agree your opinion about the wood harvest or other management activities may not change the land use type. If the forest land is cleared, the forest land will be converted to another LULC type. We revise the related description in the manuscript.

Comment 5: I found the color scale on figures 5 and 7 quite difficult to read to distinguish between the various land-use colors.

Response: Thank you for this suggestion. For figure 5, the color of pasture and grassland makes people difficult to read. We change the colors and update the figure to make it easy to read. Please see Figure R1 (Figure 8 in the revised manuscript).

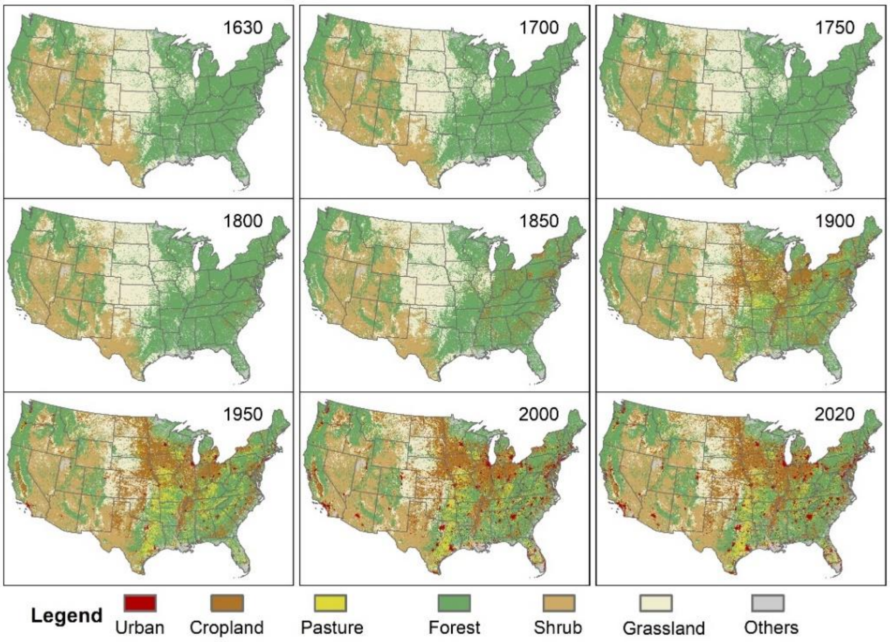


Figure R1: Spatial and temporal patterns of land use and land cover in the conterminous United States during 1630-2020.

In Figure 7, there are 12 types of LULC conversion to show and it is hard to assign a suitable color, so we add a table (Table 3) to show the LULC conversion area in four periods (1630-1850, 1850-1920, 1920-2020, and 1630-2020).

Comment 6: Overall, I think a discussion of the differences between land-use and land-cover and how that is represented in this dataset would be a helpful addition. Also, some more discussion of how this product differs from the technical details of other products and in what ways that is useful and in what ways other products might have some advantages, along with how those differences in underlying details are driving differences in the qualitative dataset results.

Response: Thank you for this suggestion. In this study, our LULC data emphasizes the accuracy of area change resulting from LULC conversion rather than the changes in LULC structure or attributes. For example, forest management (e.g., wood harvest and thinning) results in the forest cover decreases and ecosystem function change, but the LULC type and area is unchanged.

For the technical details, it should include the LULC area reconstruction strategy and spatial allocation strategy. We discussed the LULC probability calculation and spatial allocation algorithm difference between this study and other land use and land cover simulation model. In fact, the key to the spatial allocation algorithm is what ways you choose to allocate the LULC area. Some LULC simulation models allocate the LULC demand (net change) at a LULC base map and generate a new LULC map in the prediction year. But this algorithm will underestimate the gross LULC change area whatever it is used to generate fractional or Boolean type data. It is also not suitable for long-term LULC simulation, because they assumed the LULC probability or suitability surface is stable. In this study, because the contemporary LULC probability pattern is not representative for the early period, we need to modify the probability to make it close to the historical LULC pattern. Therefore, we used the spatial allocation algorithm in this study and generate a map for each year. But this strategy ignores the linkages of landscape in the neighboring two years. Please see Lines 546-567.