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Biogeosciences Discussions

Interactive comment on "A high-resolution and harmonized model approach for reconstructing and analyzing historic land changes in Europe" *by* R. Fuchs et al.

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Anonymous Referee #2

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Overall, the manuscript is of good quality, both in terms of the robustness and relevance of the work reported, and of the structure, clarity and writing of the paper itself.

For the record and clarity of the discussion, I will here re-discuss some issues raised in the preliminary screening, and whenever useful the author's responses.

I don't have major corrections to request, but I do have some remarks concerning

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Interactive Discussion

Discussion Paper

(i) some unclear aspects of the method, (ii) some of the assumptions used for the reconstructions of past land cover changes, and (iii) remarks related to the validation. ********** Unclear aspects of the methods: ********** On some unclear aspects of the methods, I had two concerns:

1/ I was not sure to understand how the authors did, given the combination of heterogeneous data sources, to make sure that the total area by country remained consistent, and no gap (area with no land cover) occurs. The authors replied by inserting a paragraph at the end of section 2.3. Their answer is satisfactory but raises an additional question. Given that they say that "To correct for discrepancies between the total area per country and the sum of all land categories, the one with the highest variance, in this case grasslands, was used to match the sum of all land categories with the total area per country", is this likely to introduce specific biases or artifacts in that grassland category, and thus how the aspects of the results and discussion that refer to the grasslands category might be affected by this part of the method?

COMMENT In the discussion we can add a sentence that this step indeed produces a bias. However, the bias is very little (ca. 1%) as compared to the overall uncertainty in the grassland category.

2/ Related to that, I'm still not sure to understand what happens with the land becoming unclassified when a land cover contracts. Does this land receives some form of priority for being reallocated to the expanding land covers? The authors write (section 2.4, p.14833) that "The area is then converted into unclassified area, which can be incorporated in other increasing classes later on as part of their increase mask (Fig. 2, middle box). Since the sum of all land categories is matched with the total area per country (see Sect. 2.2), no unclassified pixels are left after a processed time step.". And "Considering a class is increasing, it masks all other classes in the LCM and selects the highest values in the relevant probability map (PM) within this mask until the right area for that class is obtained", there is thus no mention here of a prioritization of unclassified areas for being reallocated to another land class.

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COMMENT In a revision we can add some explanation by rephrasing the current explanation: 'Every class that is increasing its area from one time step to another uses the probability map of its own class for all areas where this class can potentially grow (including unclassified areas). Since the sum of all increasing and decreasing classes is zero at the end of one time step, all unclassified areas are assigned to a class.'

********** Assumptions: **********

Further, I had two concerns about the assumptions used:

1/ The authors assume that the relations between biophysical, geographic and socioeconomic factors on one hand, and land use choices on the other hand, remain constant (i.e. the probabilities maps (PM) remain constant). The authors discuss the first assumption and replied (section 4.3, p.14845): "Although many factors are considered to be quite stable in time (e.g. climate-, terrain- and soil factors), this may have been different in the past for some of them (e.g., for accessibility or population density). However, the estimation of the probability maps has been done at national scale (with country specific factors) and was widely used and tested in multiple land use modelling efforts in a foresight mode (Verburg and Overmars, 2009; Verburg et al., 2008, 2010)". I think this deserves some more discussion. The point, by contrast with what the authors reply, is not only whether the factors are constant (e.g. climate and soils as constant factors, versus accessibility which is changing with time), but also whether the relations between land use decisions and proximate factors is changing with time. Just to give an example of the logic: when the labor versus capital intensity of agriculture changes, it is likely that the relation between population density or accessibility to settlements, and land uses is changed, as the demand for labour force changes. Similarly, depending on the dominant crop types, themselves possibly influenced by whether agriculture produces for local/regional markets or for international ones, environmental constraints differ. These are two examples of agricultural transformations which, by different degrees, affected Europe over the last decades. I indeed do take note that, as the authors explain, the factors that they used are those widely used in such types of historical land

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use reconstructions. Thus, I don't dispute that the author's work is robust compared to the usual approaches, and thus, essentially, deserves to be published as such, as long as this caveat is properly explained. But, not being directly in that field myself, I might ask the same question to authors of the other cited land use reconstructions. Some works explore sensitivity of the results to assumptions about technological factors, e.g. Kaplan's paper. But it essentially affect the total demand for land, which is here constrained by empirical data, rather than the rules governing spatial pattern. I think that this is something that could be at least discussed with reference to empirical historical studies (of land use changes in Europe, there are plenty), and deserve at least some thoughts to see how it might have influenced the results.

COMMENT The drivers of land change or changing relations of them which are mentioned (changing labor costs, changing markets and therefore different production methods) are, in our opinion, mostly determining the aggregate quantities of land change (so the statistics) rather than the spatial patterns. With a changing demand for land, which would normally result in increasing or decreasing areas, this can be seen in the statistics. It can be seen as well in our results section for the effects of the CAP (see figure 11). The CAP aimed to strengthen the agricultural sector for international competition and adjusted unit labor cost to be competitive. We tried to make our model more robust in that sense by using multiple data sets in order to verify the changes in trends over time independently, when possible. The way other researchers working on historic land reconstructions are using assumptions is different. For example the Kaplan reconstruction starts in 1850, not today. Since for that period measured data are hardly available or accessible, these approaches need to rely on assumptions (e.g. regarding technology). In our case we had measured data, which already had these developments incorporated in their area statistics, making assumptions much less important. What we cannot proof is whether a land owner would choose his land differently if he has different labor cost or when he is producing for different markets. Getting and linking such data this way is very ambitious for defining assumptions for land suitability. Furthermore, the higher the spatial resolution gets the more and differ-

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ent change patterns we see, which are harder to describe by assumptions and a land suitability. This implies that we need robust land suitability maps that are either more complex with sophisticated assumptions or use more spatially explicit land cover data of that time for decision support. The authors see the advance in the use of spatially explicit data.

2/ Similarly, the authors assume that the relation between population and settlement area remains constant. For Europe over the last half-century, this is unlikely to have been the case given the massive explosion of peri- and sub-urbanization over that period. I don't think that I have seen a response to that.

COMMENT We agree with the reviewer that our assumption is quite pragmatic and simple and that there is definitely a change in the relation between population density and urban areas over time. We can add a notion of this in the discussion section. The aggregate impact of our assumptions is validated with the aerial photos from 1950 and it appeared sufficient (see paper). Although the increase in settlement areas is quite large in comparison to the existing settlement area, it is small in comparison to all the land per country. During our study we decided that the impact on the final results is small in comparison to the required effort. For most European countries this effect was less than 1.5% in total area.

********** Validation: **********

Beyond the points discussed here above, the authors might go further on the validation of their maps, in several aspects.

First, the spatial pattern could be validated using quantitative indicators - e.g. fuzzy indicators, or Pontius and Millones 2011 approach to separate quantity and location disagreement, both overall and for the high resolution data. Second, for some countries at least, it is possible to find subnational historical data to compare with the maps, which would also allow to more precisely validate the spatial distribution of land cover changes inside countries. Third, the authors appropriately discuss the issue of land

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cover trajectories - i.e. some land cover expand preferentially over others, or are converted preferentially to some others. Indeed, the lack of gross change data prevents the explicit use of trajectories in the design of the model, but it is still possible to a posteriori validate whether the reconstructed trajectories more or less match with trajectories of change observed with higher resolution case studies. As far as I see, the authors have not addressed or discussed these issues at the stage of the technical corrections.

COMMENT Given that we allocate always exact the national quantities reported, the quantity disagreement, as identified by Pontius and others, is always 0. In the revised version of the paper we can mention this. All error identified is basically location error. The reviewer is correct that there are multiple ways of validation. In the revised paper we will indicate a stronger rationale for choosing the validation method used. This method is using high resolution data on multiple land cover types across different places in Europe. This validation actually exactly validates some of the innovative aspects of the dataset and was therefore judged appropriate. In addition, we make a comparison with existing reconstructions to estimate overall agreement with widely accepted data sources.

********** Minor issues: **********

- p.14825: “Currently, up to 30% of the global carbon emission is estimated to originate from human induced land use and land changes”: clarify that this is total historical emissions, and not current emissions rates.

COMMENT Will be changed in revised version

- p.14827: “Thus, they require high resolution data sets to observe and study these local heterogeneous processes”: such a dataset is very welcome for modelling Earth System and bio-geo-chemical fluxes, but the authors should make it clear that, for studying processes in the sense of causes, drivers, dynamics of land change, the way the dataset is constructed – as any of the similar land use reconstructions – in itself

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creates endogeneity. This dataset should thus not be used for that purposes. This is not a criticism, just a clarification to be made of the limits of this dataset.

COMMENT The HILDA data set primarily focuses on input data instead of assumptions, which should exclude the endogenity problem. The demand of land (with implied causes, drivers and dynamics) is based on the input data, their change trends over time (also in relation to each other) and the fact that only 100% of land area is available.

- p.14829: "While remote sensing data could provide spatially explicit land cover and use information and its changes, it temporally covers only a relatively small proportion of the investigated time frame (1990s – 2010 vs. 1950 – 2010)." Actually, Landsat 1 (with MSS) was launched in 1972, and Landsat 4 (the first with TM) in 1982, but this does not undermine the whole argument that reconstructions are needed.

COMMENT True. We actually meant remote sensing products (e.g. Corine, which is operationally available since 1990) and not data. We will change that term.

- p.14829 (l.24): "trans. shrub" : put "transitional"

COMMENT Will be changed in the revised version

- p.14929: is there a rationale for including wetland in the grassland category rather than in "Other Land"?

COMMENT Yes, there is. Our other land class comprises primarily non-vegetated land forms like dunes, glaciers, bare soils, water and so on. Wetlands are vegetated areas for most of the time in form of grasslands, meadows, shrubslands, peatlands etc., that is why we included wetlands in the grassland class.

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