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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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This manuscript describes a fine-scale land cover reconstruction for the EU-27 for the period 1950-2010. Such a set of maps is a potentially important dataset for a range of applications, including better GHG accounting. The paper represents a major advance compared to existing datasets in terms of resolution, disaggregation methodology, and input data used. I have a few comments and suggestions for revisions that would further strengthen the paper.

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MAJOR COMMENTS BY REVIEWER

P 14831 I1-5: Is it realistic to assume that population density in urban areas in Europe over the last 50 years can be reasonably well approximated based on the year 2000? Did you consider spatial variation in settlement density across Europe?

AUTHORS COMMENT We agree with the reviewer that this assumption can be debated. And we agree that there is definitely a change in the relation between population density and urban areas over time. We therefore tried to validate our assumption with the aerial photos from 1950. 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. These results indicate that the model outcomes based on this assumption are reasonable. In the revised version we can add a bit of discussion on this assumption.

Did you consider spatial variation in settlement density across Europe?

AUTHORS COMMENT Yes, we did by applying the specific population/area relation to every country separately.

P 14831 I21-28 (and entire section 2.3): The assumption that the land suitability function was constant across the entire time period and can be reasonable well estimated from the year 2000 data seems very bold. Given the strong transformation of land use systems during this time period (e.g., major mechanization trends, strong increase in chemical fertilizer use, drastic decrease in labor force) and major changes in the demand side (e.g., population growth and changing consumption patterns) it is unrealistic that the suitability of a particular location for any given land use would not change. Likewise, was there no spatial variability incorporated? Given the heterogeneity in land use histories in European countries (e.g., different EU accession dates, West vs East, etc) the use of a global appears too simple.

AUTHORS COMMENT We agree that it is true that some of the allocation factors influence the probability maps in time (e.g. population density and accessibility), but on the

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other hand most of the allocations remain quite stable across longer time periods (e.g. climate, terrain, soil factors). In the revised version we can add some more discussion on the assumption and its possible consequences as well as on other potential drivers not considered in this study. This discussion can stress that the drivers of land change which are mentioned (major mechanization trends, strong increase in chemical fertilizers use, drastic decrease in labor force, different EU accession dates, etc.) are mostly incorporated in the land demand part (so the statistics). For example, a major mechanization and increase of fertilizer use in agriculture led to less demand in cropland area, since the yield was higher. This can already be seen in almost every European cropland statistic, of which HILDA makes use.

P14834 I 3-10: Related to the above, if there were 73 sites of 30x 30 km² available for validation, why were these sites not used to estimate the suitability functions for the two different time periods? Or could these sites for example be used to provide some evidence for the assumption that the suitability functions were indeed stable?

AUTHORS COMMENT For these data windows only land cover pattern data were available and not time series of the patterns in location factors. Although we appreciate the suggestion made by the reviewer, it is unfortunately not possible to make this assessment.

P14837 I27 –P14839 I25: While the visual comparison is interesting, I would like to see a more thorough accuracy assessment. Given that the authors had 73 fairly large test sites, you could easily draw a stratified random sample from the downscaled land cover maps and evaluate these points against the reference maps, and calculate true area estimates and confidence intervals around them. Given that the 73 sites are a non-random selection, it would be important to correct for potential sampling bias (see Olofsson et al. for details: <http://www.sciencedirect.com/science/article/pii/S0034425712004191>). Since the air photos cover only 1950 and 1990, GoogleEarth high-resolution images could be used for an assessment of the recent (+/- 2010) maps.

AUTHORS COMMENT We see the point of the reviewer and will address this issue in the revised version. Using Google Earth would certainly not be the best option, since the aerial or satellite photos of the various sample sites may vary within time and spatial resolution. Google Earth would not be a guarantee for +/- 2010 maps. Furthermore, the images are not classified, which makes its use difficult without any class nomenclature, ground data and spectral information to assign the classes correctly. Especially between grassland and cropland (with a potential fallow) this can be tricky and cause more uncertainty.

P14841 – entire section 4.1.2: The discussion of the forestry sector 1950-today seems very general and focusses exclusively on Western Europe. This section should be expanded, and it would be good to clearly distinguish forest management (e.g., logging) from land use change (e.g., abandonment and subsequent forest expansion).

AUTHORS COMMENT In the revision we can discuss the reforestation of Eastern Europe (Baltics as example) from section 4.1.4 in a bit more detail and possibly add some other eastern European examples. We agree on the comment that we should distinguish more clearly between management and land cover change.

P14841 I4.1.3: Why is agricultural land management / land use change BEFORE the introduction of the CAP not discussed at all? Many of the countries modeled in this study were longer outside the EU than inside it during the study period. Even more importantly: why is agriculture in Eastern Europe before the EU-accession not discussed at all? A large part of the EU27 was socialist before 1989 and land management paradigms and land change pathways were very different there (highlighting again the problematic assumption that land suitability was the same 1950-today). I would recommend to expand this section to represent better the variation in policies and land management pathways in Europe.

AUTHORS COMMENT In the paper we discussed a number of main processes of change. We tried to focus on the main patterns, such as the ones related to CAP or

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the Fall of the Iron Curtain. Often change patterns like land abandonment go in parallel with others, such as reforestation (e.g. in the Baltics). We described this cascade of changes in other sections (e.g. section 4.1.4) and in relation to its previous state. In the revision we can also add some more information on this topic.

P14844 – section 4.2.2: Again, this is a fairly weak section. There was a lot more regional variety than the authors acknowledge. What does “could not compete with the market” mean? Also, there was a lot of land use change in Eastern Europe already before the collapse of the Soviet Bloc (see comment above on pre-accession agricultural change).

AUTHORS COMMENT In the revision we will add some more information for eastern Europe before the collapse of the Soviet Bloc.

P14845 I4-12: This section refers to the assumption of stable land suitability. Could you do a sensitivity analyses to build confidence that relaxing this assumption does not affect your main conclusions and land use/cover patterns?

AUTHORS COMMENT This is a good comment, but it is difficult to estimate the range of deviation from stability, since most of the suitability factors are more compound multi-factor equations and there is no simple way to estimate how ‘non stable’ relations would vary. However, we can provide some information for e.g. the influence of varying population density on urban areas by adding some test cases in the supplementary material (e.g. in steps of 10% changes of population density).

MINOR COMMENTS BY REVIEWER

P 14826 I5: Could you be more specific as to what the “spatial, temporal, and thematic” limitations of existing datasets are? This requires more detail given that this is the major motivation for the downscaling exercise carried out.

AUTHORS COMMENT Details are already given in Table 1. The need for downscaling will be better addressed in the revision.

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P14826 I23-24: Given that many satellites acquire data in a systematic, standardized way, isn't the ability to map large regions and to compare across political boundaries rather a strength than a weakness of remote sensing?

AUTHORS COMMENT We agree with the reviewer that this is a strength of remote sensing if all data are processed in the same way by the same provider. In practice, mostly classification products produced at the national level according to national nomenclature and standards are used.

P 14828 I1-14: The methods 'summary' paragraph could be deleted.

AUTHORS COMMENT If needed this paragraph can be deleted in the revisions.

P 14828 I17-25: Given that it is argued in the intro that current datasets are coarse, inconsistent across borders, and not very detailed in time, the beginning of section 2.2 seems a bit contradictory. Why are many of these datasets now used as input data if they are problematic? Also, how was the 1990-2010 period used to "inter-calibrate" these datasets that differ substantially in scale, timer periods, etc.? This needs a more thorough explanation.

AUTHORS COMMENT Contrary to other studies, we used multiple temporal overlapping data and harmonized them to verify the country specific trends. The offsets of the various input data arise mainly due to differences in class definitions (e.g. for forests with different definitions for density and tree height). This appears not only between the different data sets but also along the countries' boundaries, since they often use their national definitions. For different data with overlapping periods, remote sensing products can be used to inter-calibrate the offsets in the total amount with statistics, since their class definition and class accuracy is better described (especially for CORINE it is well documented). This allows to have a higher confidence of class assignment in the harmonization process.

P 14845 I20-29: I am not sure I understand why only net changes were available – did

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you not use a range of maps (CORINE, GlobCORINE, UMD, etc.) which would allow estimating gross changes? Were net changes used for all period?

AUTHORS COMMENT In the revision we can include more information about the differences between net and gross changes and the reasons why the HILDA product may underestimate the gross change. We will quantify this based on the CORINE 1990-2006 comparison of net/gross change to give an order of magnitude for this difference. We will also indicate that a full consideration of the gross/net changes is not possible for our product as this would require the comparison of consistent spatially explicit maps or statistics covering the whole period, which account for gross changes (often these statistics were obtained from remote sensing products). The only product where a comparison would make sense, was the CORINE data set with the time steps 1990, 2000 and 2006. Unfortunately CORINE does not cover the whole period. The UMD data set uses data of a roughly 20 year period, which makes it difficult to account for changes when comparing with other data sets. The GlobCORINE data set comprises only a few years (2005 and 2009) and the period is covered as well by the CORINE data sets. The statistics we used only accounted for the total area of a land cover class. So, we were missing the information of the change matrix. Additionally all these maps are affected by misclassification which increase the uncertainty of the gross change estimation.

Were net changes used for all period?

AUTHORS COMMENT Yes.

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