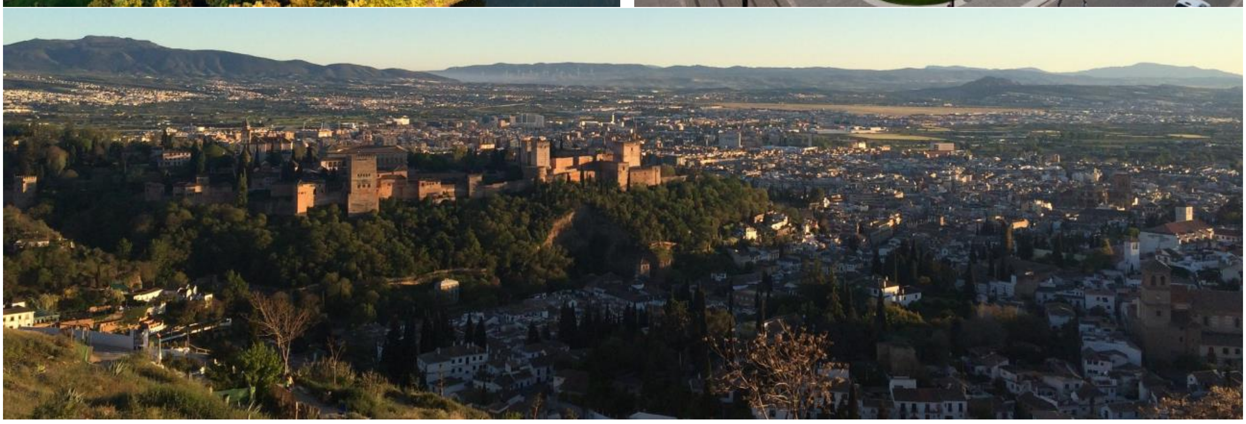
ETC/ULS Technical Report | 01/2021

Time series inconsistency in the Copernicus HRL Imperviousness

Analysis of the 2015-2018 changes, implications and conclusions



Authors:
Mirko Gregor, Manuel Löhnertz (s4e), Roger Milego, Jaume Fons (UAB), Gergely Maucha (Lechner), Emanuele Mancosu (UMA), Andreas Littkopf (EAA), Eva Ivits (EEA)

European Environment Agency
European Topic Centre on Urban, Land and Soil Systems

Cover photos:
Upper left © Jakub Karas, My City /EEA
Upper right © Birta Larisa, My City /EEA
Bottom © Gonzalo Esteban, My City /EEA

More information on the ETC/ULS is available on the Internet at https://www.eionet.europa.eu/etcs/etc-uls.

European Topic Centre on Urban, Land and Soil Systems (ETC/ULS)
Environment Agency Austria
Spittelauer Lände 5
A-1090 Vienna/Austria

Tel.: +43 1 313 04
Fax: +43 1 313 04/5400

Web: https://www.eionet.europa.eu/etcs/etc-uls

Contents

1 The situation

A land cover (land use) map is always an abstraction, a model of the real earth surface. Features represented in this model are influenced by many factors, including the classification system, scale / level of generalization (e.g., Minimum Mapping Unit or MMU) and other mapping instructions as well as possible database errors. As long as the data model is consistent within a time series, changes and trends derived by pixel- or grid-based approaches ("pixel counting") may be meaningful, i.e., valid within the same model (e.g., Corine Land Cover or CLC accounting). This is in fact the core idea of "pixel counting" based accounting systems.

Copernicus High Resolution Layers (HRLs) are Earth Observation (EO)-derived and raster-based datasets which provide information about different land cover characteristics, such as impervious (sealed) surfaces, forest areas, grasslands, water & wetlands, and small woody features. The longest and most complete time-series is available for the HRL Imperviousness products, with the first status layer being available for the reference year 2006, then 2009, 2012, 2015 and 2018. Change information are available for all change periods (both, density change and change classified). Primary 20m resolution (and aggregated 100m resolution) products were harmonized for the 2006-2015 period in a way that imperviousness status and change layers build a consistent time series, where imperviousness density changes are equal to the difference of subsequent imperviousness status layers (see Figure 1-1 and Figure 1-2, blue bars at the left until reference year 2015 and change period 2012-2015, respectively).

However, the introduction of the increased 10m resolution in case of all primary HRLs caused unexpected issues. The great advantage of the increased resolution has led to the appearance of more feature details. On the flipside, this fact has made the new 10m resolution imperviousness product inconsistent with the previous time series especially in a statistical sense. While the estimated increase of sealed surfaces was between 1 and 2% across Europe in the previous 3 years periods (1,7% between 2006 and 2009, 1,8% between 2009 and 2012, and 1,2% between 2012 and 2015, based on the 20m resolution data, see the three blue bars on the left in Figure 1-2), the increase equalled to around 26% between the 20m resolution IMD2015 and the 10m resolution IMD2018 status products which is due to the many more sealed surfaces captured by the higher resolution 2018 product.

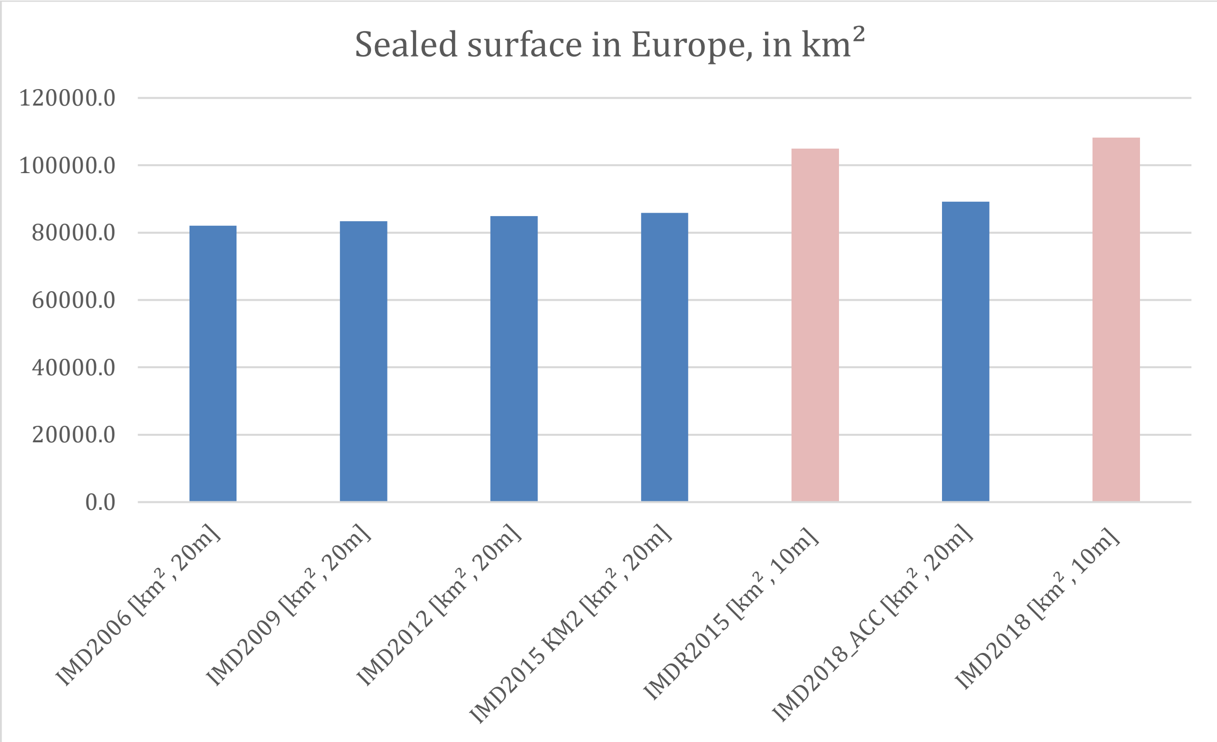


Figure 1-1: Sealed surface in Europe (in km²); the blue bars represent values based on 20m data (2018 calculated by ETC/ULS), the light red bars represent 10m data

There exists an additional 10m HRL IMD layer for 2015 (Consultancy layer, called IMDR2015, see first light red bar in Figure 1-1) that was produced by the service provider (SP, the producer of the HRLs). <u>When looking at the change between 2015-2018 using the 10m datasets, it accounts for a 3.1% increase, i.e., an acceleration of the trend of sealed surface increase across Europe</u> (see light red bar in Figure 1-2). This increase is also bigger than previous increases (even though less than when comparing the IMD2015 20m and the IMD2018 10m). But they cannot be compared mainly due to the change in spatial resolution: we simply don't know what the figures would have been (absolute and relative) in previous periods with 10m imperviousness measurements.

In general, the comparison of area statistics derived from different models has significant limitations. Sealed areas estimated by the HRL IMD will be certainly different from an estimation derived from CLC, while CLC based and, e.g., Urban Atlas based values will be different because of the details appearing in the product, the kind of abstraction used in the model (class definitions) and other factors. In this sense 20m IMD layers represent a different model than the 10m ones, as obviously much more details appear in 10m resolution. The consequence is limited comparability.

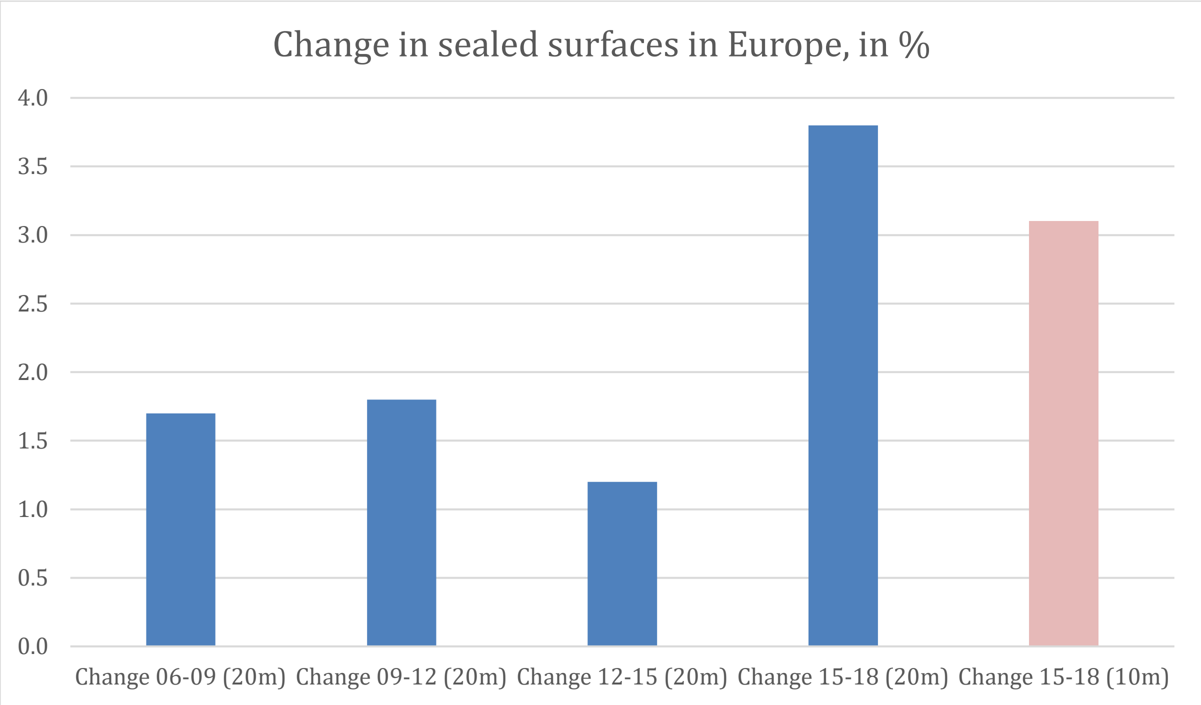


Figure 1-2: Change in sealed surfaces in Europe (in %); the blue bars represent values based on 20m data (2018 calculated by ETC/ULS on the basis of the IMC real changes between 2015 and 2018), the light red bars represent 10m data

In order to resolve the above issue several approaches were implemented. The service providers were asked to separate the "real imperviousness change signal" (IMC standard product) from the "technical imperviousness change signal" (IMCS technical product). Including a support layer to remove technical changes (IMCS2018) only led to a decrease of this increase of 2,5% from 26% (see one of the previous paragraphs) to 23,6%. This implies that the removal of technical changes does not sufficiently eliminate the changes solely introduced by the increase of the spatial resolution. As part of ETC/ULS work, an "IMD2018 accounting" layer (20m resolution) has been calculated by combining the 20m / 100m IMD2015 and IMC1518 (real imperviousness change) layers. However, the resulting "IMD2018 accounting" layer (see total sealed area value in right blue bar in Figure 1-1) still shows an around 3 times larger sealing increase (3,8%) compared to the 2015 status as in previous periods (see the right blue bar in Figure 1-2). This value is to a certain extent in line with the change derived from the 10m data (3,1%, light red bar in Figure 1-2), but doesn't seem to be consistent with previous periods.

In early 2021, the service provider was tasked with executing a bias correction of the 10m imperviousness data. This analysis that was carried out at a national level found out that unlike the EO-based raster data indicate, there is no acceleration of sealing in Europe, but rather a substantial deceleration. Even though a bias correction should not lead to a substantial correction of a validated data set, the message is contradictory to both the 20m and 10m trends identified from the spatial imperviousness layers, i.e., it provides yet another picture of reality.

2 Implications of data and methodological changes on other Copernicus products

With the introduction of the 10m EO data as basis for the HRL production, the data model of the HRL IMD became inconsistent, i.e., the long time series is broken and we are talking about two time series (2006-2015 with 20m resolution and from 2018 onwards with 10m resolution; there is no way to use and assess changes between 2015 and 2018 at the moment). As a consequence, any assessment and product that is dependent on the time series has to be broken down into two parts. This concerns the following products and collaborations:

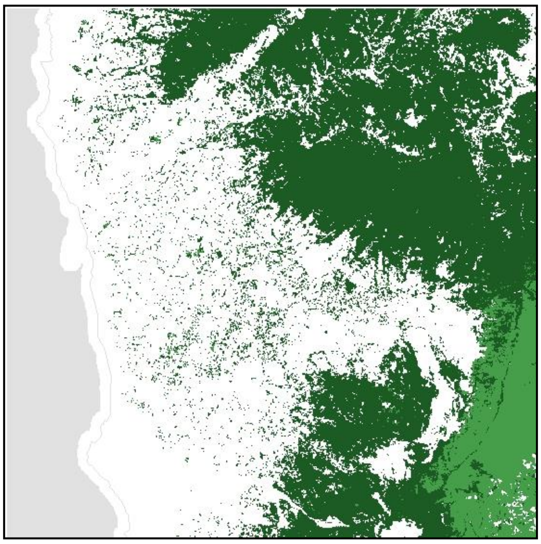
- Imperviousness indicator;

- Urban sprawl/DIS calculation;
- Landscape fragmentation indicator;
- Land take report;
- Enhanced CLC;
- CLMS made easy (dashboards);
- Service Level Agreement (SLA) with DG REGIO; and
- The State of the Environment Report (SOER) 2025.

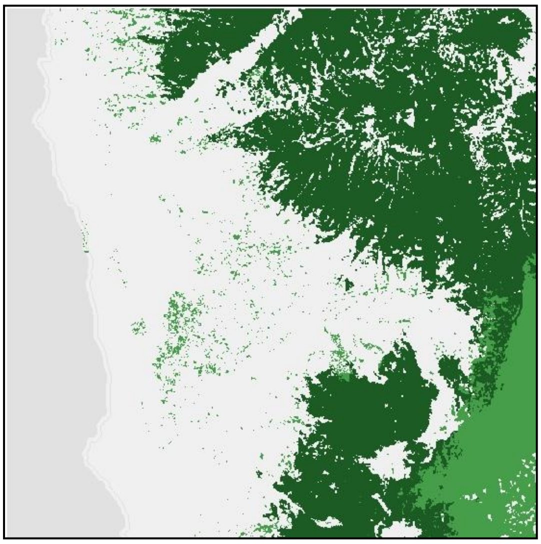
In addition to the interruption of the long time series and based on (i) the differences between the data sets (SP and ETC/ULS), as well as (ii) the strong discrepancy with the previous change trends, we do not think that the layer reflects the real situation properly. It is hard to believe that the previous trend of sealing increase in Europe should have experienced such a dramatic acceleration in just three years. On top of it, the bias correction also indicates that this observation seems to be wrong.

Analysing the HRL Forest layers it also becomes obvious that the time series will need to be split up due to the input data and methodological changes; moreover, there also seem to be inconsistencies in the previous change period 2012-2015 which seem to stem from errors in the 2012 data (see Figure 2-1).

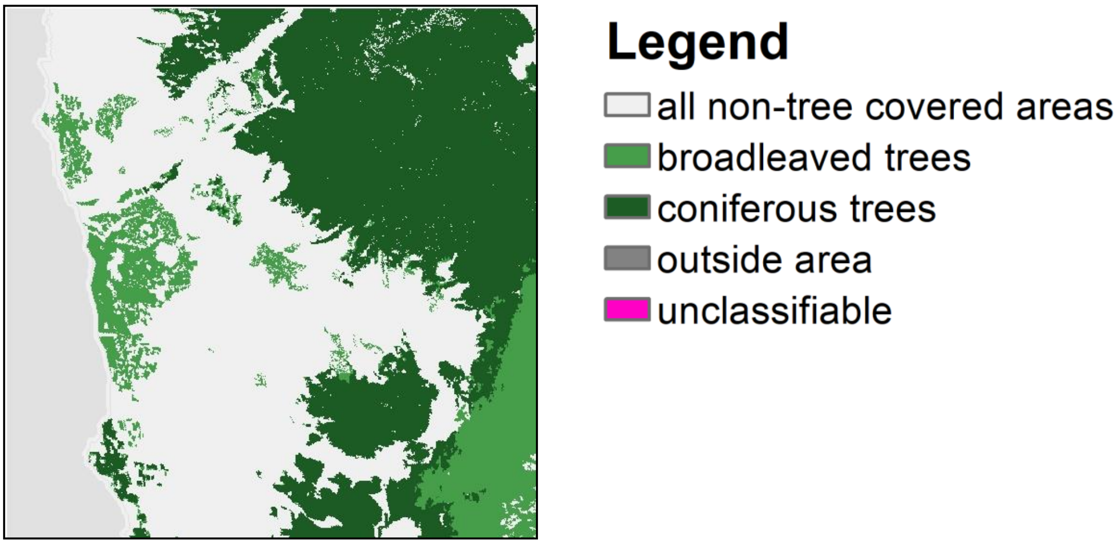
In essence, it means that any assessment can only employ the recent 2018 HRL data as status information (all HRL products) and no consistent time series information can be provided.



HRL Dominant Leaf Type - DLT2018



HRL Dominant Leaf Type - DLT2015



HRL Dominant Leaf Type - DLT2012

Figure 2-1: Illustration of inconsistencies in the time series of HRL Dominant Leaf Type status (La Palma, Canarias, Spain)

Another implication of the issues with the HRL IMD concerns the local component hotspot product Urban Atlas. The Urban Atlas nomenclature subdivides urban residential fabric into continuous urban fabric (class code 11100) and four discontinuous urban fabric classes (11210-11240). The HRL IMD data set is used for discriminating those classes by means of sealing thresholds (see Figure 2-2). As the production of the Urban Atlas and HRL IMD overlapped for the reference years 2006, 2012 and 2018, it seems obvious to us that the general increase of sealing levels in 2018 (caused by the higher resolution of the input satellite data) will lead to changes in the assignment of the urban fabric categories as well.

1		Artificial surfaces	
1.1		Urban Fabric	
1.1.1	**11100**	**Continuous urban fabric (S.L. > 80%)**	HRL IMD required
1.1.2		Discontinuous Urban Fabric (S.L. 10% - 80%)	
1.1.2.1	**11210**	**Discontinuous dense urban fabric (S.L. 50% - 80%)**	HRL IMD required
1.1.2.2	**11220**	**Discontinuous medium density urban fabric (S.L. 30% - 50%)**	HRL IMD required
1.1.2.3	**11230**	**Discontinuous low density urban fabric (S.L. 10% - 30%)**	HRL IMD required
1.1.2.4	**11240**	**Discontinuous very low density urban fabric (S.L. < 10%)**	HRL IMD required

Figure 2-2: Subdivision of the urban fabric in the Urban Atlas nomenclature

An analysis of the area shares of those urban fabric classes indeed indicates that there is a general trend of changes from a class with lower density into a class with higher density, e.g., from 11240 in 2012 into 11220 or 11210 in 2018 (see orange squares in Figure 2-3). This doesn't seem to be a real change, but a side effect of the increased sealing levels that leads to polygons being assigned to a more strongly sealed class.

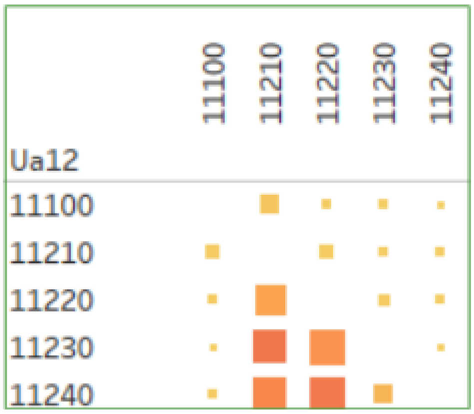


Figure 2-3: Changes of Urban Atlas classes between 2012 (rows) and 2018 (columns)

To go further down the product chain, these (technical) changes lead to errors in the land recycling indicator values (see Figure 2-4).

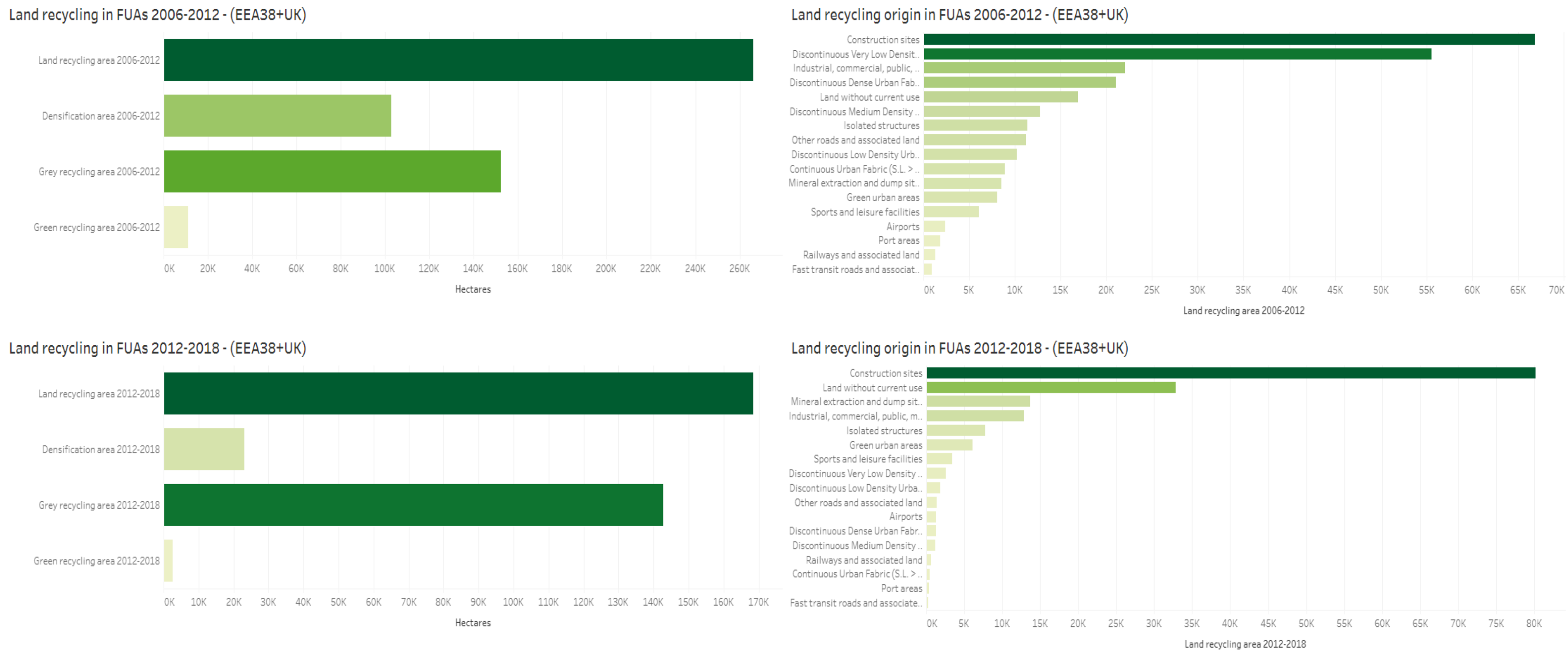


Figure 2-4: Land recycling dashboard (unpublished)

Looking at the graphs, there are two facts supporting our conviction that there is an issue propagated from the HRL IMD input data change into the Urban Atlas:

- Even though the change period 2012-2018 covers way more than two times the amount of FUAs than the change period before (788 compared to 319 FUAs), there is in total almost 100 thousand hectares less recycled area (left side of the graphs in Figure 2-4).
- While apart from construction sites (which need their own discussion in the context of land recycling) the different discontinuous urban fabric classes were the main original classes for land recycling between 2006 and 2012, they are only "also-rans" between 2012 and 2018 (right side of the graphs in Figure 2-4).

What is also visible from the graphs is that densification is no longer the dominant land recycling process which it has been (see indicator assessment at https://www.eea.europa.eu/data-and-maps/indicators/land-recycling-and-densification/assessment-1) before the delivery of the updated Urban Atlas 2012 being part of the data package of the Urban Atlas 2018. This finding was confirmed by the service provider informing that they used non-harmonised IMD data for the production of the Urban Atlas.

As a consequence, from the points listed before we don't think that the land recycling indicator can be produced this year as land recycling is a process whose assessment relies on consistent time series, in particular the sub-process densification. The current Urban Atlas time series does not provide this consistency.

In addition to the temporal inconsistencies, we have discovered discrepancies between the Functional Urban Area (FUA) boundaries the Urban Atlas uses and the ones that are provided by Eurostat/GISCO for the Urban Audit[1], i.e., spatial inconsistencies. As Figure 2-5 shows, the two boundaries do not match, in some areas the Urban Audit coverage extends over the borders of the Urban Atlas coverage (pink in the left image), in other areas it is vice versa (green in the right image). This means the reference unit for the spatial Land Use / Land Cover (LULC) data does not entirely match the reference unit for the statistical data which might lead to an incomparability of spatial and statistical data as they do not exactly represent the same surface area. In addition, France possesses more Urban Atlas FUAs than Urban Audit FUAs (see Figure 2-6). And lastly, the FUA boundaries for the West Balkan countries and Turkey had to be created separately from additional data sources (as documented in the "First Interim Project Report" issued by the service provider team of the Copernicus Lot 1 Urban Atlas) which led to outlines that are obviously different than the Urban Audit ones and also show inconsistencies in terms of coverage (e.g. cities are bigger than their FUA, see Figure 2-7) and coding (multi-part city polygons with overlapping or missing codes, see Figure 2-8).

Those differences are due to the fact that the official Urban Audit delineations are regularly updated to include administrative or morphological changes in FUAs. The production of Urban Atlas, on the other hand, uses a specific Urban Audit version, fixed in time at a certain moment, for the sake of consistency. More specifically, the delineation of FUAs within Urban Atlas 2012 and 2018 (for the Copernicus Land Monitoring Service) has two sources:

1. EU-27 and the UK, Switzerland, and Iceland: provided by DG Regio to EEA in Autumn 2017 (originated in Member States and collected originally by Eurostat).
2. West Balkans and Turkey delineated for EEA by Urban Atlas service providers. The task was conducted during the first quarter of 2017 and the results validated by EEA and DG REGIO by

[1] https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit

the end of March. 107 Functional Urban Areas have been defined over this geographical extension; the methodology applied is the OECD-EC definition from 2012.

Therefore, all the updates or changes in FUA delineations after Autumn 2017 are not reflected in the delineations of the FUAs in Urban Atlas.

In future updates, we strongly suggest finding a way to harmonize FUA delineations to make the comparison of FUAs throughout the longest time-series possible.

Figure 2-5: Overlay of Urban Atlas FUA boundaries (green) and the official Eurostat/GISCO Urban Audit boundaries (pink)

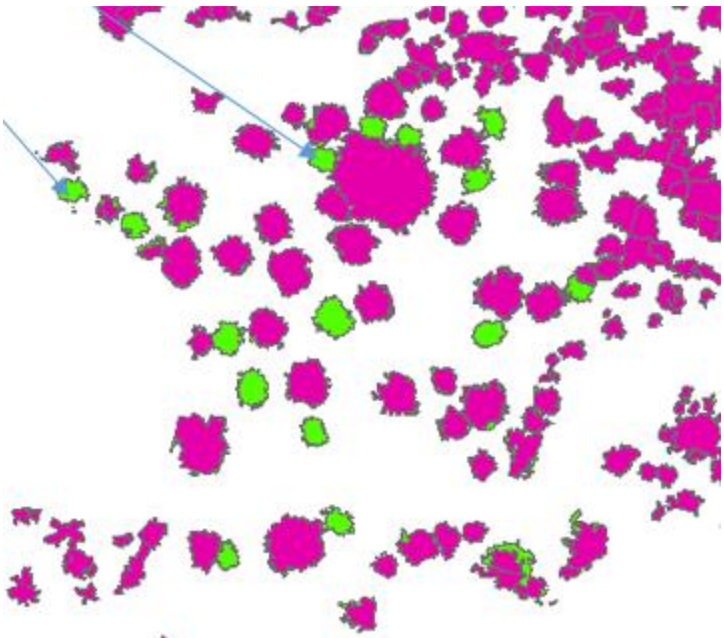
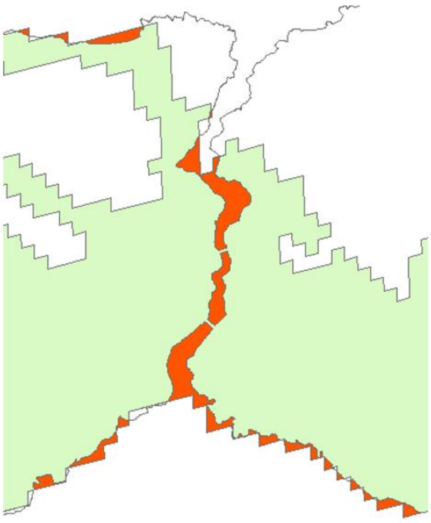
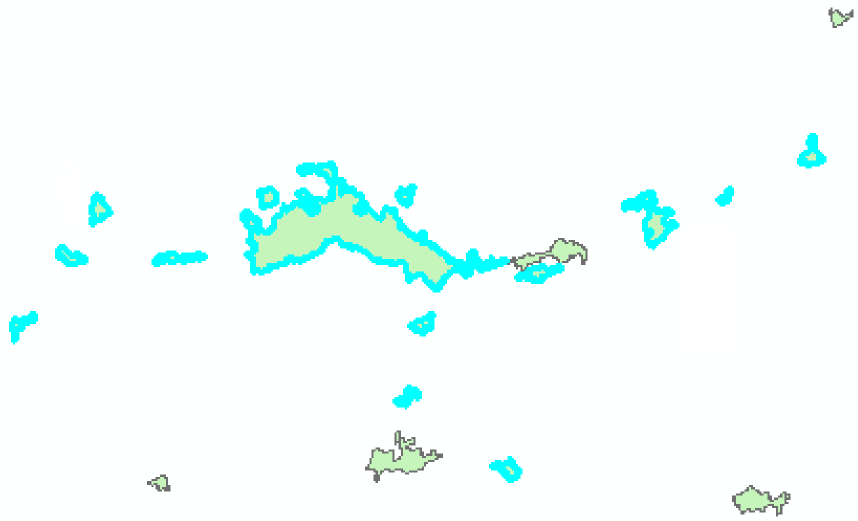


Figure 2-6: Urban Atlas (green) and Urban Audit (pink) FUA boundaries in France and neighbouring regions



FID	Shape	URAU_CODE	CNTR_CODE	URAU_NAME	fua_code	fua_name
0	Polygon	AL001C1	AL	Tirana(FUA name)	AL001L1	Tirana
1	Polygon	AL003C1	AL	Elbasan(FUA name)	AL003L1	Elbasan
2	Polygon	AL004C1	AL	Shkodër(FUA name)	AL004L1	Shkodër
3	Polygon	BA001C1	BA	Sarajevo(FUA name)	BA001L1	Sarajevo
4	Polygon	BA002C1	BA	Banja Luka(FUA name)	BA002L1	Banja Luka
5	Polygon	BA003C1	BA	Mostar(FUA name)	BA003L1	Mostar
6	Polygon	BA004C1	BA	Tuzla(FUA name)	BA004L1	Tuzla
7	Polygon	BA005C1	BA	Zenica(FUA name)	BA005L1	Zenica
8	Polygon	ME001C1	ME	Podgorica(FUA name)	ME001L1	Podgorica
9	Polygon	MK001C1	MK	Skopje(FUA name)	MK001L1	Skopje
10	Polygon	MK003C1	MK	Bitola(FUA name)	MK003L1	Bitola

Figure 2-7: Urban Atlas FUA and City boundaries in Istanbul (Turkey)



ua2018_city_laea_v5

FID	Shape *	OBJECTID	CNTR_ID	URAU_CODE	URAU_CATG	SHAPE_AREA	SHAPE_LEN	OBJECTID_1	URAU_COD_1	URAU_CAT_1	CNTR_CODE	URAU_NAME	CAPITAL_CI	CITY_IN_KE	FUA_CODE	NUTS3_2016	AREA_SQM	ID_cc	cc_code
1028	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Cerkezkoy	N				0	1029	TR012
1029	Polygon	0		TR012C1	C	1921150090.82	0	0			TR		N				0	1030	TR012
1030	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Corlu	N				0	1031	TR012
1031	Polygon	0		TR012C1	C	1921150090.82	0	0			TR		N				0	1032	TR012
1032	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Silivri	N				0	1033	TR012
1033	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Tekirdag	N				0	1034	TR012
1034	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Duzce	N				0	1035	TR012
1035	Polygon	0		TR012C1	C	1921150090.82	0	0			TR		N				0	1036	TR012
1036	Polygon	0		TR012C1	C	1921150090.82	0	0			TR		N				0	1037	TR012
1037	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Istanbul	N				0	1038	TR012
1038	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Adapazar	N				0	1039	TR012
1039	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Golcuk	N				0	1040	TR012
1040	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Yalova	N				0	1041	TR012
1041	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Gemlik	N				0	1042	TR012
1042	Polygon	0		TR012C1	C	1921150090.82	0	0			TR	Inegol	N				0	1043	TR012

Figure 2-8: Overlapping polygons with erroneous or missing city codes/names

3 Conclusions

Taking into account the assessments of the data reported in the previous chapters, we come to the following conclusions:

- EO input data and methodological changes lead to an inconsistency in the time series of the HRL IMD data and most probably all other HRLs as well. While there is no doubt that the spatial resolution of the HRL improved substantially, the impact of these changes on the change products and the time series are equally substantial.

- As a consequence, the interruption in the time series leads to the presence of two time series and status information as beginning of a new time series, respectively: pre-2018 and 2018 and beyond. Change information between the reference years 2015 (HRLs) or 2012 (Urban Atlas) and 2018 cannot be used.
- Beyond the data products themselves (HRLs with HRL IMD having the longest coverage), the time series discontinuity also affects many other Copernicus and EEA products and indicators and renders the temporal assessment usually associated with indicators and data products with a temporal component useless. There is only the option to look at the time series up to 2015 with a resolution of 20m and restart a new time series with a spatially improved product in 2018.
- Next to the indicators which are directly depending on the HRL IMD (such as imperviousness and imperviousness change, urban sprawl, landscape fragmentation to name but a few), the downstream effect of the observed issue with the HRL IMD can be exemplified by looking at the impact on the Urban Atlas data and the derived indicator on land recycling.
- Lastly, the time series discontinuity also affected or affects some planned publications of the EEA (supported by ETC/ULS), such as the indicator assessments on imperviousness, landscape fragmentation (both can only be produced as a status assessment) and land recycling (needs to be cancelled). The land take report had to be reframed to cover urban areas only. Moreover, a planned collaboration with DG REGIO (by means of an SLA) had to be reviewed. But even more importantly, the lack of long-term harmonised time series will also put the preparation of the SOER 2025 in danger as there will most probably only be one further status layer available (reference year 2021) until 2024 when most of the SOER has to be produced.

In any case, a collaboration or close exchange with the service provider (e.g., for the bias correction), the Eionet Action Group on Land Monitoring in Europe (EAGLE) group and National Reference Centres (NRCs) is recommended. There needs to be a European-wide discussion on this topic as it in the end not only affects the HRL IMD, but also the HRL Forest (with a time series that started in 2012). The final goal must be to achieve a harmonized, consistent time series of all products. Ultimately, they should also be consistent at grid cell or pixel level to allow for a correct and reliable accounting of geospatial information.

European Topic Centre on Urban, Land and Soil Systems (ETC/ULS)
Environment Agency Austria
Spittelauer Lände 5
A-1090 Vienna/Austria
Tel.: +43 1 313 04
Fax: +43 1 313 04/5400

Web: https://www.eionet.europa.eu/etcs/etc-uls

The European Topic Centre on Urban Land and Soil Systems (ETC/ULS) is a consortium of European institutes under contract of the European Environment Agency.

European Environment Agency
European Topic Centre on Urban, Land and Soil Systems