

Copernicus Land Monitoring Service – High Resolution Layer Imperviousness

Product Specifications



Copernicus land monitoring service – High Resolution Layer Imperviousness: Product Specifications Document

Title	Copernicus Land Monitoring Service – High Resolution Layer Imperviousness: Product Specifications Document
Creator	Tobias LANGANKE
Creation date	2016-03-10
Subject	Definitions and product specifications of Copernicus High Resolution Layer Imperviousness products
Status	Final
Publisher	Copernicus team at EEA
Type	Text
Description	This document contains detailed product definitions and specifications for the pan-European Copernicus High Resolution Layer Imperviousness. It was created in close collaboration and with contributions from the service providers in a consultative process.
Contributor	Magdalena STEIDL (GeoVille), Christian SCHLEICHER (GeoVille); Christophe SANNIER (SIRS)
Format	Word document
Source	European Environment Agency
Rights	European Environment Agency
Identifier	This is version 1 of 2018-12-21
Language	EN
Relation	Copernicus regulation
Coverage	2018

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ABBREVIATIONS & ACRONYMS

CLC	CORINE Land Cover
CLMS	Copernicus Land Monitoring Service
EEA	European Environment Agency
EEA39	39 member and cooperating countries of the EEA
EO	Earth Observation
ETC	European Topic Centre
GIO	GMES/Copernicus initial operations
HR	High Resolution
HRL	High Resolution Layer
IMC	Degree of Imperviousness change
IMCC	Degree of Imperviousness change classified
IMD	Degree of Imperviousness
LAEA	Lambert Azimuthal Equal-Area
MMU	Minimum Mapping Unit
NDVI	Normalised Difference Vegetation Index
PSU	Primary Sampling Unit
SSU	Secondary Sampling Unit
SWIR	Short-wavelength infrared
TIF	Tagged Image File Format
VHR	Very High Resolution

1. Background

This document captures the detailed definitions and product specifications for the Copernicus Land Monitoring Service (CLMC) Imperviousness High Resolution Layer (HRL) for the 2015 reference year and the re-processing of the 2006-2009-2012 imperviousness products, including change products.

The document evolved during the production period as a specification document and was then adopted for the final users of the datasets.

2. Product overview

Built-up areas are characterized by the substitution of the original (semi-) natural cover or water surface with an artificial, often impervious cover. These artificial surfaces are usually characterized by long cover duration¹. A series of high resolution imperviousness datasets (new for 2015 and re-processed for all previous reference years) with all artificially sealed areas was produced using automatic derivation based on calibrated NDVI².

This series of imperviousness layers constitute the main status layers. They are per-pixel estimates of impermeable cover of soil (in other words: soil sealing) and are mapped as the degree of imperviousness (0-100%). Imperviousness change layers were produced as a difference between the corresponding reference dates and are presented as degree of imperviousness change (-100% -- +100%). An additional classified (categorical) 20m change product is included.

2.1 Definition of Imperviousness Products

Considering the experiences of previous productions and the results of the product validation, we tried to ensure that the following land cover classes are correctly classified as built-up or non-built-up:

- a) Objects corresponding to CLC classes 1.3.x (mines, quarries, dump sites and construction sites), which are wrongly considered impervious surfaces.
- b) Greenhouses and permanent plastic covered soil shall be classified as impervious surface.
- c) Green roofs should not be classified as impervious surfaces, despite their function as largely sealed surface
- d) Beaches, dunes, sand (associated to CLC class 3.3.1), bare rocks (CLC 3.3.2) and sparsely vegetated areas (CLC 3.3.3) and are common sources for misclassification. They do not belong to impervious surfaces.

¹ FAO Land Cover Classification System, 2005

² Normalised Difference Vegetation Index

- e) Airports and harbours are another common sources of misclassification and should be corrected regarding both commission and omission errors.

The separation of built-up / non-built-up areas represents a kind of stratification and is based on the list of included / excluded elements. Table 1 shows the elements that are included / excluded. This list was created by the revision of the corresponding list applied in GIO.

Table 1: Elements to be included and excluded from the Imperviousness mapping

Elements to be included ³ in the Imperviousness Mapping 2006, 2009, 2012 and 2015	Elements to be excluded from Imperviousness Mapping 2006, 2009, 2012 and 2015
<ul style="list-style-type: none"> • Housing areas (even with scattered houses) • Traffic areas (airports, harbours, railway yards, parking lots) • Roads⁴ • Railway tracks associated to other impervious surfaces (i.e. inside built-up area) • Industrial, commercial areas, factories, energy production and distribution facilities • Sealed surfaces, which are part of categories, such as e.g. allotment gardens, cemeteries, sport and recreation areas, camp sites, excluding green areas associated with them • Artificial grass-covered sport pitches • Construction sites with discernible evolving built-up structures. • Single (farm) houses (where possible to identify from satellite imagery) • Paved borders of water edges • Greenhouses • Permanent plastic covered soil • Solar panel parks 	<ul style="list-style-type: none"> • Construction sites without discernible evolving built-up structures • Temporal plastic coverage on agricultural fields • Railway tracks not associated to other impervious surfaces (i.e. outside built-up area) • Mines, quarries, peat extraction areas • Sand, sand pits • Dump sites • Natural, artificial and cultivated vegetated areas • Un-vegetated or sparsely vegetated areas • Un-vegetated agricultural fields, arable land • Vineyards, fruit plantations • Grass surfaces used for sports of any kind • Glaciers, snow, water • Green roofs

³ Description of included land cover types is harmonized with the EAGLE data model's terminology, which is formulated to be in line with INSPIRE data specification terminologies wherever possible. Description of included land cover types is harmonized with the EAGLE data model's terminology, which is formulated to be in line with INSPIRE data specification terminologies wherever possible. Terminology quoted from deliverable '1_A1_EAGLE_ConceptExplDocumentation_v2.3.pdf' of Final Report of Restricted procedure No EEA/MDI/14/009.

⁴ Roads are captured with no requirement of creating un-interrupted linear features, which would require the use of additional road network data in the classification. This means that gaps in imperviousness values will continue to occur, in particular for smaller roads.

The separation of candidate built-up / non built-up areas was performed using a sophisticated semi-automatic methodology. Since not all the elements in the list may be separated clearly with automated classification methods, the use of in-situ information was necessary.

Non-built up areas are characterized by definition with IMD = 0% value, while built-up areas are characterized by IMD values 1-100%.

The delivery of reliable imperviousness change information over time is of key importance for the user. This was ensured with the production of well calibrated IMD status layers. The re-processing of all previous density products (Degree of Imperviousness 2006, 2009, 2012) was necessary to ensure proper absolute and relative calibration of datasets. Calibration datasets were required as a deliverable, but were only produced and delivered in 20m spatial resolution, European Projection. They are kept as internal products for reference in future exercises, but are available on request.

Imperviousness products are grouped as follows:

- Reference/calibration products (Reference database)
- Primary products
- Derived products

2.1.1 Reference/calibration products (Reference database)

Newly sealed areas and its sealing degrees are usually detected reliably even in previous productions. In order to increase the accuracy of sealing degree estimations, and its changes within already sealed areas, an absolute calibration of the imperviousness values was performed with an independent imperviousness value reference database, which was explicitly established for this purpose on base of VHR data (IMAGE 2015). For the prediction of the imperviousness degree a (multi)linear regression method was used, to model the relationship between the collected reference samples (IMD_{real}) and meaningful metrics from the biophysical variables (e.g. $NDVI_{max}$, $NDVI_{min}$, etc.) derived from the seasonal image composites.

In order to build up a **Reference Database for absolute Calibration** of imperviousness density, imperviousness density values have to be interpreted on the basis of VHR EO data (preferably IMAGE 2015 VHR) for selected sample cells within the European LAEA 100m reference grid. 5 strata are differentiated on the basis of previous 2006, 2009 and 2012 imperviousness layers over stable areas (i.e. same IMD density value [1-100%] observed over the time-series). Strata are defined by equal intervals of imperviousness density values:

- IMD Strata:
1. 1% to 20%
 2. 21% to 40%
 3. 41% to 60%

4. 61% to 80%

5. 81 to 100%

A maximum of 180 Primary Sampling Units (PSUs) - 36 in each stratum - are randomly selected for each sampling frame. One sampling frame covers an area of 300km by 300km and consists of 3*3 connected cells of the EEA 100km Reference Grid (see Figure 1). The number of PSUs is reduced proportionally to the decreasing rate of imperviousness layer coverage per sampling frame. A minimum number of 10,000 PSUs within 150 sampling frames are considered for EEA39. The initial idea based on the LUCAS sampling scheme is finally not implemented, as it cannot ensure to get the minimum required number and distribution of PSUs in each sampling frame.

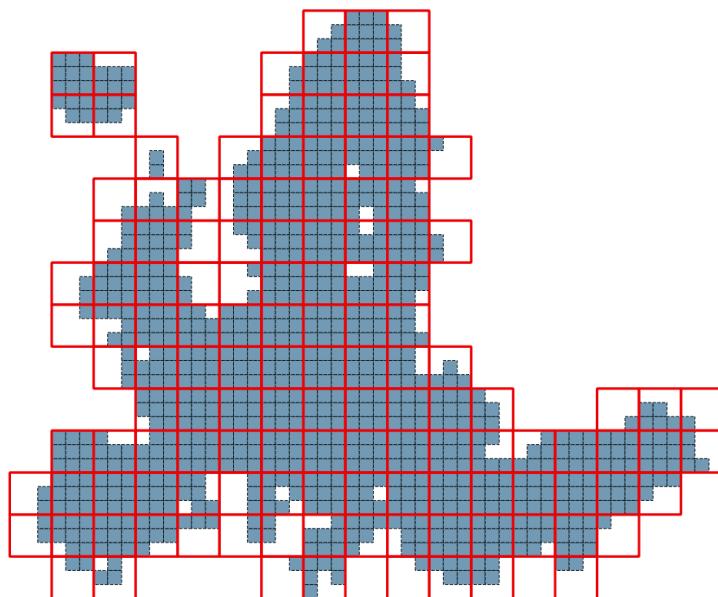


Figure 1: Sampling frame (red) and underlying 100km EEA Reference Grid

Secondary Sampling Units (SSUs) are generated on the basis of a 5x5 systematic grid of points within each PSU for which the imperviousness degree value is below 30 % or above 70 %. A 10x10 grid is used for the medium density strata (31 %-70 %) because of higher uncertainty (see figure Figure 2).



Figure 2. Example of SSUs organised in a 5x5 20m (left) and a 10x10 grid (right)

In addition to the Reference Database for absolute Calibration (see above) a **Reference Database for Change Calibration** was set up in order to perform a statistical as well as a spatial calibration of the changes between the status layers of 2006, 2009, 2012 and 2015. This step was performed in order to improve the consistency between all status layers and the change layers.

The calibration dataset for the changes is based on a probability sampling approach, in the same way as the sampling for the Reference Database for absolute Calibration but focussing only on the change areas. The change areas were compared with ancillary data as e.g. Open Street Map, to identify potential errors in the change layers. Those errors were flagged and subsequently corrected to improve the quality of the status layers and the change layers.



Figure 3: Example of potential commission errors in the status and subsequently the change layers based on comparison with ancillary data (OSM product)

2.1.2 Primary products (status layers)

Primary products were produced via semi-automatic processing of EO satellite imagery. Improvements and corrections including (re-)calibration and manual enhancement (correcting omission / commission errors) were applied on primary layers to derive the primary products.

The primary products represent the status of the imperviousness degree for a specific year by considering EO Image date from the status year and the year before and after the represented status year, in order to ensure sufficient EO image coverage.

Image data gaps are limited to a minimum because of the integration of multi-temporal image data per season. Even so image data gap still occur and were filled by assigning “unclassifiable” (class 254) or “no data” (255).

2.1.3 Derived products (change layers)

Derived products are all products derived from the primary products by means of standardized GIS processes (aggregation, re-projection, subtraction for deriving the change layers).

Required derived products are:

- Imperviousness change classified layers in 20m resolution (European & national projection)
- Aggregated Imperviousness density layers in 100m resolution (European & national projection)
- Imperviousness density change layers in 20m and 100m resolution (European & national projection)

2.1.4 Re-Projection and Aggregation

In order to keep the consistency between the status and the change layers of the national products in 20m and in 100m resolution the 20m primary product is first re-projected. For each country specific projection the change layers and the classified change layers are calculated before the individual derived country specific products are aggregated to 100m. Performing the re-projection and aggregation in that order avoids artefacts that can be caused by the re-projection and related re-sampling of the layers.

In Figure 4 the flow of change layer calculation, re-projection and aggregation for the main products is visualised. This figure also shows the dependencies of one product from the other.

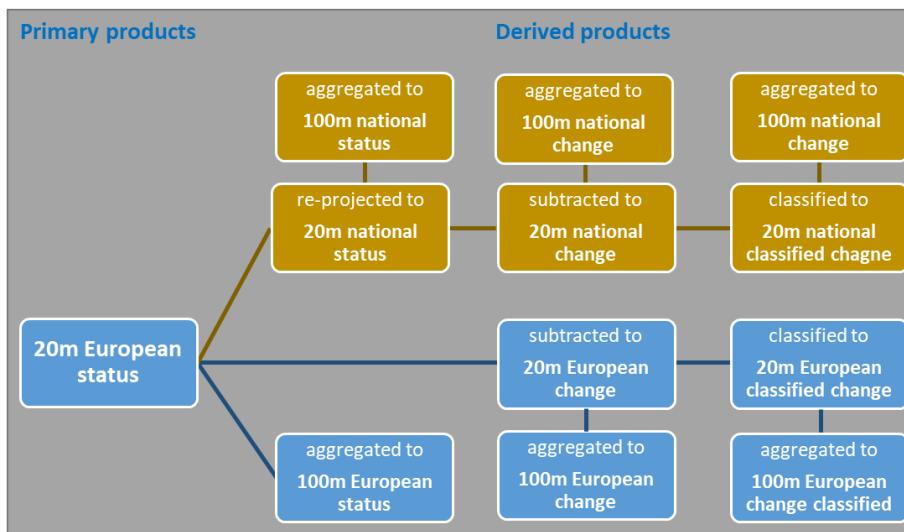


Figure 4: Re-projection and aggregation workflow

3. Methodology

3.1 HRL Imperviousness 2015

The methodology applied for the production of the HRL imperviousness allows to derive the degree of imperviousness in a robust, reliable and reproducible way out of high resolution satellite images (IRS-P6/Resourcesat-2 LISS-III, SPOT 5 and Landsat 8).

The production is based on a supervised classification of built-up/non-built-up areas with subsequent visual improvement of classification results and derivation of degree of imperviousness based on continuous multi-temporal seasonal image composites (3 per year). Thus, the influences of seasonal variations of vegetation cover to the imperviousness degree was limited.

The final result is a raster dataset of built-up and non-built-up areas including the degree of imperviousness from 0-100 with a spatial resolution of 20 x 20m.

Production steps:

1. Usage of a 100 x 100 km tiles based on the EEA reference grid as production units
2. Creation of three multi-seasonal image composites (spring-summer-autumn 2014-2016) per 100 x 100 km tile
3. Derivation of biophysical variables (NDVI) per input image
4. Mosaicking of single NDVI images to maximum NDVI mosaics per 100 x 100 km tile
5. Automated derivation of classification training samples from additional reference data (CLC, HR layers)
6. Automated supervised classification of built-up and non-built-up areas

7. Combination of classification result with the built-up masks from the HRL Imperviousness 2012 and 2006 to determine built-up changes and possible omission and commission errors
8. Visual correction and supplementation of derived built-up change candidates
9. Absolute calibration of the maximum NDVI for calculating the degree of imperviousness based on the Reference Database for absolute Calibration.

Applied European Boundaries

For delineation of the production area (EEA39) a combination of the EuroBoundaryMap v11 (EBM) and GISCO boundaries has been used for the 20m HRL Imperviousness 2015 status and all change products.

3.2 HRL Imperviousness 2006, 2009 and 2012 – re-processed status layers

The derivation of Imperviousness 2006-2009-2012 consists of two separate procedures, the re-processing and the re-analysis of the historical layers. The methodologies applied for both the re-processing, and re-analysis of all existing density products, assure a properly calibrated HRL Imperviousness time-series. It has to be taken into account that no complete re-production of the historic data sets was performed. Instead a re-processing and re-analysis of the existing IMD 2006-2009-2012 status products utilizing the re-processed historic IMAGE2006, 2009 and 2012 images was done. The final result are raster datasets of built-up and non-built-up areas including the degree of imperviousness from 0-100% with a spatial resolution of 20 x 20m.

Production steps:

1. Re-analysis of density values
 - 1.1. Application of a relative calibration to the historical IMD2012 layer based on the absolutely calibrated IMD2015 density values. Therefore, a tile-based moving-window approach was applied in two steps:
Step 1: alignment of the historical IMD values through adaptation of image statistics
Step 2: rule-based approach to maintain consistency of IMD values
 - 1.2. Subsequent application of a relative calibration to the historical IMD2009 and IMD2006 layer based on the IMD2012 and IMD2009 density values, respectively.
Again, a tile-based moving-window approach was applied in two steps:
Step 1: alignment of the historical IMD values through adaptation of image statistics
Step 2: rule-based approach to maintain consistency of IMD values
2. Re-processing of the built-up outlines:

- 2.1. Subtraction of the built-up outlines of 2006 and 2015 derived during the production of the IMD2015 status layer
 - 2.2. Derivation and visual interpretation of re-processing samples (PSUs) within change areas in order to get statistics concerning amount of real changes and commission errors
 - 2.3. Dependent on the derived statistics, performance of an independent classification of change areas based on the re-processing samples or class assignment based on intersections with the historical layers of 2009 and 2012
 - 2.4. Manual quality check of the change areas
 - 2.5. Derivation of the built-up outlines for 2006, 2009 and 2012
3. Combination of built-up outlines and re-calibrated imperviousness density values to derive the re-processed historical IMD status layers
 4. Reconstructing of historical cloud masks and application to the re-processed IMD status products.

Applied European Boundaries (Coastline)

For the historical status products of 2006, 2009 and 2012 the maximum extent of the combination of the hybrid version of the EBM v11 and the GISCO boundaries and the original outer boundaries of the respective year was considered. Specifically, the hybrid boundary was used in all areas where its extent is equal or larger than the original outline of the historical layer. For those cases, as far as data gaps between the original extent of the historical layer and the hybrid border exist, these were filled with the raster value 254 (unclassifiable). For all other areas the original extent of the historical layer defines the outer boundary of the layer.

Cloud areas in historical layers

In the initial production of the status layers 2009 and 2012 cloud areas were filled with imperviousness values from the previous status layer were the imperviousness degree was > 0 . For the processing of the status layer of 2015 and the re-processing of the historical layers in the frame of the 2015 HRL production it was requested not to indicate un-reliable imperviousness information, e.g. by filling cloud areas in one status layer with imperviousness values from the previous status layer.

However, as the re-establishment of the explicit cloud coverage of the historical layers of 2012 was not feasible because of missing metadata information, reliable imperviousness values even in potential cloud areas were kept but pixels that could not explicitly determined because of unclassifiable data were indicated as unclassifiable (pixel code 254). That was done by applying the following approach:

- a) cloud areas in 2009 and 2012 were filled with values of either 2006/2012 or respectively 2009/2015 in case no imperviousness density change took place from the previous to the following status year directly adjacent to the corresponding status layer.
- b) for 2009 the existent metadata on clouds were used to intersect cloud areas with areas where an imperviousness density change took place to identify non-reliable imperviousness values. Those areas/pixels were classified as "unclassifiable" (254)
- c) for 2012 cloud masks were established based on information of the clouds indicated in the status layer and re-established cloud masks from image data. These areas were intersected with the areas where an imperviousness change took place to identify non-reliable imperviousness pixels. Those areas/pixels were classified as "unclassifiable" (254)

Compared to previous exercises, for the production of the status layer of 2015 continuous multi-temporal seasonal composites – three calibrated full image data coverages for entire EEA39 for the years 2014/2015/2016 – are established and subsequently integrated in the classification process.

3.3 HRL Imperviousness change 06-09, 09-12, 12-15, and 06-12

To derive the Imperviousness change 2006-2009, 2009-2012 and 2006-2012 layers the respective IMD status layers, which were either newly produced or re-processed, are subtracted from each other after considering a rule based adaptation of the historical layers. The classified change is derived by aggregating the IMD change values in specified change classes. The final result are raster datasets of imperviousness degree change including change values from -100 to 100 and raster datasets of classified imperviousness change including defined classes as unchanged areas, new cover, loss of cover, and imperviousness degree increase and decrease. All layers are delivered with a spatial resolution of 20 x 20m.

Production steps:

1. Subtraction of the respective IMD status layers for change layer calculation between 2006-2009, 2009-2012, 2012-2015, and 2006-2012
2. Derivation of IMC 2006-2009, IMC 2009-2012, IMC 2012-2015, and IMC 2006-2012
3. Thematically aggregation of change values into categorical classes based on the defined rule set for the classified change product
4. Derivation of IMCC 2006-2009, IMCC 2009-2012, IMCC 2012-2015, and IMCC 2006-2012

In previous HRL Imperviousness projects in the frame of Geoland2 and GIO-land, only a 100m imperviousness change layer were produced. There, for the establishment of the 100m change product, thresholds for imperviousness degree changes were applied to the 20m status layer

before aggregation to the 100m status layer, while the 20m status layer was kept as is. The change layer then was calculated by subtracting the aggregated 100m status layers. Hence, no consistency was kept between the 20m status and the 100m status layer.

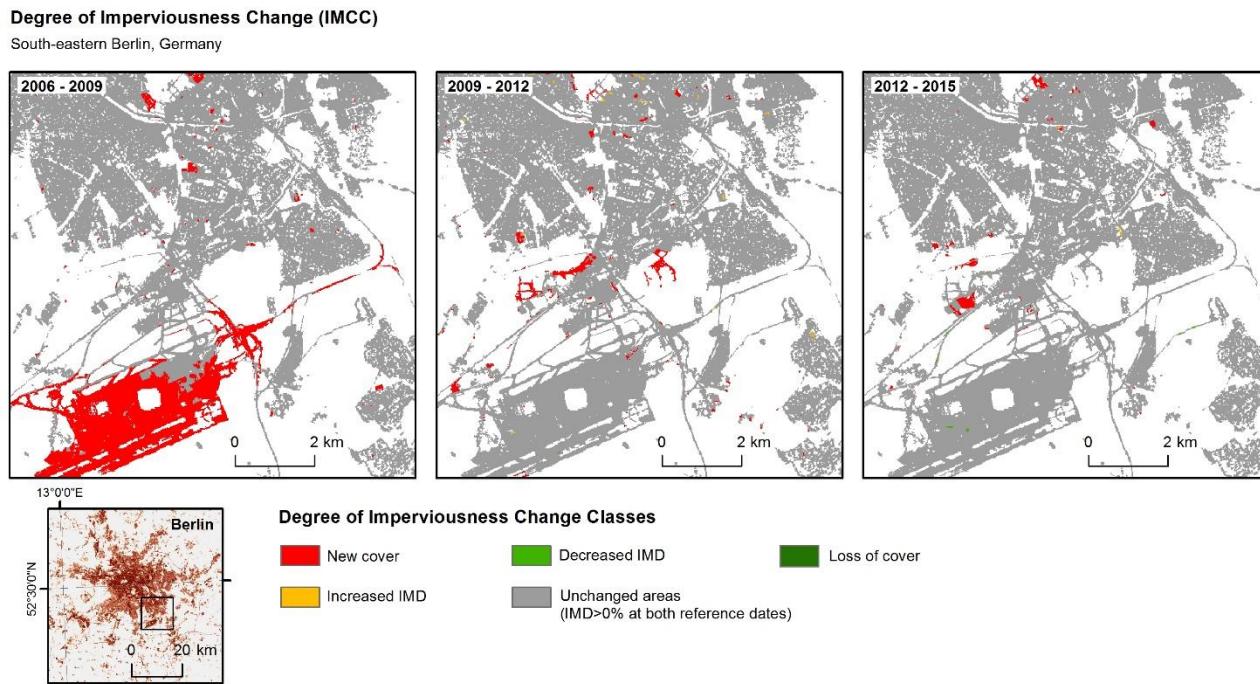


Figure 5: Degree of Imperviousness Change (IMCC 20m) in three-year intervals from 2006 to 2015. Example taken from south-eastern Berlin showing the construction of the new Berlin Airport (former Schönefeld Airport).

In order to ensure the consistency between the status and the change layers for the current production for new and re-processed Imperviousness layers, a rule-based procedure was applied. This was also necessary to reduce the effect of sealing values (changes) that are introduced by the variance of input data quality and the limited number of image coverages available for the processing of the historical layers. To deal with strong fluctuations in sealing densities especially in low density areas it was required to apply a dynamic threshold for sealing increase. Hence, differences below the dynamic threshold for sealing increase were considered as stable, as a lower threshold would cause a too high level of false detected changes. In the case of sealing decrease it is assumed that this is generally rare and, if occurring, it will rather be a loss of an impervious surface than an actual decrease. Most captured decreases would therefore not indicate actual changes, but only differences in input data quality. Considering this, no inner-urban density decrease is accepted, but only the complete loss of sealing. The applied rules for the adaptation of the status layers are explained in the following table:

Table 2: Rules for adaptation of IMD values of historical layers

Result from comparison	Rules for adaption of IMD values
1. IMD2012 = non-built-up IMD2015 = built-up	Keep IMD2012 value of 0%
2. IMD2012 = built-up IMD2015 = non-built-up	Keep IMD2012 value
3. IMD2012 = IMD2015	Keep IMD2012 value
4. IMD2012 < IMD2015	Assign IMD2015 value, i.e. snap IMD2012 values to IMD2015 within stable built-up areas. A threshold of 20% for the difference between 2012 and 2015 was applied. This value was adapted iteratively in case of general underestimation of historical sealing values.
5. IMD2012 > IMD2015	Assign IMD2015 value, i.e. cap all IMD2012 to IMD2015 within stable built-up areas.
Specific rules for the application for the re-processed historical layers	
6. IMD2009 < IMD2012 IMD2006 < IMD2009 (change exceeds a difference of 20%)	Accept identified change (e.g. increase from IMD2009 to 2012) if a contiguous area of ≥ 4 px is concerned; otherwise assign IMD value of the most actual layer.
7. IMD2009 > IMD2012 IMD2006 > IMD2009	Assign IMD value of the subsequent layer.

The same rules for 2012 and 2015 were applied for the 2009-12 and 2006-09 periods with consideration of the specific rules for historical layers indicated in the table above.

The methods applied for the production of the HRL Imperviousness 2015 (i.e. the relative and absolute calibration of the data) and the increased quality and quantity of considered input data (i.e. application of multi-temporal image coverage) lead to more stable and reliable estimation of sealing degrees. If the method of relative and absolute calibration and an improved image database will be considered for further updates, the thresholds can be further reduced and the quality of the change products further increased.

3.4 HRL Imperviousness 100m aggregated products

The 20m HRL Imperviousness status layers were aggregated to 100m basically based on a majority rule for valid and invalid pixels. To derive a 100m raster in a concise way, all 25

underlying 20m pixels were considered. The aggregation is therefore based on standardized GIS processes and specific aggregation rulesets which were applied to the data. The change layer itself was not aggregated directly, but derived from the 100m status products, similar to the change calculation workflow of the 20m products.

Table 3: Rules for aggregation of IMD status product to 100m

Aggregation rules for the IMD status product	
Invalid pixels	<p>If the majority of 20m pixels within a 100m cell is outside area (pixel value 255) or unclassifiable (pixel value 254):</p> <p>Outside area (255) pixels >= unclassifiable (254) pixels?</p> <ul style="list-style-type: none"> • Yes: assign "no data (255)" to the cell • No: assign "unclassifiable (254)" to the cell <p>In case of equality assign 255</p>
Valid pixels	<p>If the majority (>=13) of 20m pixels within a 100m cell has a valid value (other than 254 / 255):</p> <p>If one underlying pixel is unclassifiable (pixel value 254) within the valid pixel mask than unclassifiable (254) is assigned.</p> <p>If all values are other than unclassifiable (254) within the valid pixel mask the average value is calculated taking into account the impervious values (pixel values 0 to 100) only.</p>

4. Detailed product tables

Table 4: Reference products for calibration

	Name of product	Reference year	Raster coding
Reference products for calibration and biophysical parameters	Degree of Imperviousness (vector layer of selected 100mx100m cells of European LAEA reference grid)	Preferably 2015, but newest available	0: non sealed 1-100: IMD values 255: outside area
	Sealing reference (point grid within the selected 100mx100m sample cells)	Preferably 2015, but newest available	0: non sealed 1: sealed soil 2: sealed soil (covered by tree crowns)
	Biophysical parameters most relevant for		Scaling according to output values

	production, as a minimum: NDVI		
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Table 5: Detailed table with all imperviousness deliverables, excluding the reference products. Please note that all deliverables in 20m and 100m are listed separately, as well as all products in national projection.

No	Name of product	Rfr. year	Draft Abbreviation	Pixel size	Project ion	MMU	Re-projected	Re-sampled from 20m	Classified feature	Raster coding
1	Degree of Imperviousness 2015, 20 m	2015	IMD_2015_020m	20 m	LAEA	20 m	NO	NO	Degree of imperviousness 1-100%	0: all non-impervious areas 1-100: imperviousness values 254: unclassifiable 255: outside area Degree of imperviousness
2	Degree of Imperviousness 2015, 20 m	2015	IMD_2015_020m	20 m	National	20 m	YES	NO	Degree of imperviousness 1-100%	
3	Degree of Imperviousness 2015, 100 m	2015	IMD_2015_100m	100 m	LAEA)	20 m	NO	YES	Degree of imperviousness 1-100%	
4	Degree of Imperviousness 2015, 100 m	2015	IMD_2015_100m	100 m	National	20 m	YES	YES	Degree of imperviousness 1-100%	
5	Degree of Imperviousness, re-processed, 20 m, 2006	2006	IMD_2006_020m	20 m	LAEA	20 m	NO	NO	Degree of imperviousness 1-100%	
6	Degree of Imperviousness, re-processed, 20 m, 2009	2009	IMD_2009020m	20 m	LAEA	20 m	NO	NO	Degree of imperviousness 1-100%	
7	Degree of Imperviousness, re-processed, 20 m, 2012	2012	IMD_2012_020m	20 m	LAEA	20 m	NO	NO	Degree of imperviousness 1-100%	
8	Degree of Imperviousness, re-	2006	IMD_2006_100m	100 m	LAEA	20 m	NO	YES	Degree of imperviousness 1-100%	

No	Name of product	Rfr. year	Draft Abbreviation	Pixel size	Project ion	MMU	Re-projected	Re-sampled from 20m	Classified feature	Raster coding
	processed, 100 m, 2006									
9	Degree of Imperviousness, re-processed, 100 m, 2009	2009	IMD_2009_100m	100 m	LAEA	20 m	NO	YES	Degree of imperviousness 1-100%	
10	Degree of Imperviousness, re-processed, 100 m, 2012	2012	IMD_2012_100m	100 m	LAEA	20 m	NO	YES	Degree of imperviousness 1-100%	
11	Degree of Imperviousness, re-processed, 20 m, 2006	2006	IMD_2006_020m	20 m	National	20 m	YES	NO	Degree of imperviousness 1-100%	
12	Degree of Imperviousness, re-processed, 20 m, 2009	2009	IMD_2009_020m	20 m	National	20 m	YES	NO	Degree of imperviousness 1-100%	
13	Degree of Imperviousness, re-processed, 20 m, 2012	2012	IMD_2012_020m	20 m	National	20 m	YES	NO	Degree of imperviousness 1-100%	
14	Degree of Imperviousness, re-processed, 100 m, 2006	2006	IMD_2006_100m	100 m	National	20 m	YES	YES	Degree of imperviousness 1-100%	
15	Degree of Imperviousness, re-processed, 100 m, 2009	2009	IMD_2009_100m	100 m	National	20 m	YES	YES	Degree of imperviousness 1-100%	
16	Degree of Imperviousness, re-	2012	IMD_2012_100m	100 m	National	20 m	YES	YES	Degree of imperviousness 1-100%	

No	Name of product	Rfr. year	Draft Abbreviation	Pixel size	Projection	MMU	Re-projected	Re-sampled from 20m	Classified feature	Raster coding
	processed, 100 m, 2012									
17	Degree of Imperviousness change, re-processed, 20 m, 2006-2009	2006-2009	IMC_0609_020m	20 m	LAEA	NO	NO	NO	Degree of imperviousness change negative change -100 to -1 %, positive change 1-100 %	0-99% decrease (0 = 100% decrease, 99 = 1% decrease) 100 stable built-up 101-200 increase (101 = 1% increase, 200 = 100% increase) 201 stable non built-up 254 unclassifiable 255 outside area-
18	Degree of Imperviousness change, re-processed, 20 m, 2009-2012	2009-2012	IMC_0912_020m	20 m	LAEA	NO	NO	NO		
19	Degree of Imperviousness change, 20 m, 2006-2012	2006-2012	IMC_0612_020m	20 m	LAEA	NO	NO	NO		
20	Degree of Imperviousness change, 20 m, 2012-2015	2012-2015	IMC_1215_020m	20 m	LAEA	NO	NO	NO		
21	Degree of Imperviousness change, re-processed, 100 m, 2006-2009	2006-2009	IMC_0609_100m	100 m	LAEA	NO	NO	YES		
22	Degree of Imperviousness change, re-processed, 100 m, 2009-2012	2009-2012	IMC_0912_100m	100 m	LAEA	NO	NO	YES		
23	Degree of Imperviousness change, 100 m, 2006-2012	2006-2012	IMC_0612_100m	100 m	LAEA	NO	NO	YES		
24	Degree of Imperviousness change,	2012-2015	IMC_1215_100m	100 m	LAEA	NO	NO	YES		

No	Name of product	Rfr. year	Draft Abbreviation	Pixel size	Project ion	MMU	Re-projected	Re-sampled from 20m	Classified feature	Raster coding
	100 m, 2012-2015									
25	Degree of Imperviousness change, re-processed, 20 m, 2006-2009	2006-2009	IMC_0609_020m	20 m	National	NO	YES	NO		
26	Degree of Imperviousness change, re-processed, 20 m, 2009-2012	2009-2012	IMC_0912_020m	20 m	National	NO	YES	NO		
27	Degree of Imperviousness change, 20 m, 2006-2012	2006-2012	IMC_0612_020m	20 m	National	NO	YES	NO		
28	Degree of Imperviousness change, 20 m, 2012-2015	2012-2015	IMC_1215_020m	20 m	National	NO	YES	NO		
29	Degree of Imperviousness change, re-processed, 100 m, 2006-2009	2006-2009	IMC_0609_100m	100 m	National	NO	YES	YES		
30	Degree of Imperviousness change, re-processed, 100 m, 2009-2012	2009-2012	IMC_0912_100m	100 m	National	NO	YES	YES		
31	Degree of Imperviousness change, 100 m, 2006-2012	2006-2012	IMC_0612_100m	100 m	National	NO	YES	YES		
32	Degree of Imperviousness change,	2012-2015	IMC_1215_100m	100 m	National	NO	YES	YES		

No	Name of product	Rfr. year	Draft Abbreviation	Pixel size	Project ion	MMU	Re-projected	Re-sampled from 20m	Classified feature	Raster coding
	100 m, 2012-2015									
33	Degree of Imperviousness change classified, 20 m, 2006-2009	2006-2009	IMCC_0609_20m	20 m	LAEA	NO	NO	NO	Degree of imperviousness change classified	0: unchanged areas with imperviousness degree of 0 1: new cover - increased imperviousness density, zero IMD at first reference date 2: loss of cover - decreasing imperviousness density, zero IMD at second reference date 10: unchanged areas, IMD>0 at both reference date 11: increased imperviousness density, IMD>0 at both reference date 12: decreased imperviousness density, IMD>0 at both reference date 254: unclassifiable in any of parent status layers 255: outside area
34	Degree of Imperviousness change classified, 20 m, 2009-2012	2009-2012	IMCC_0912_020m	20 m	LAEA	NO	NO	NO		
35	Degree of Imperviousness change classified, 20 m, 2006-2012	2006-2012	IMCC_0612_020m	20 m	LAEA	NO	NO	NO		
36	Degree of Imperviousness change classified, 20 m, 2012-2015	2012-2015	IMCC_1215_020m	20 m	LAEA	NO	NO	NO		
37	Degree of Imperviousness change classified, 20 m, 2006-2009	2006-2009	IMCC_0609_020m	20 m	National	NO	YES	NO		
38	Degree of Imperviousness change classified, 20 m, 2009-2012	2009-2012	IMCC_0912_020m	20 m	National	NO	YES	NO		
39	Degree of Imperviousness change classified, 20 m, 2006-2012	2006-2012	IMCC_0612_020m	20 m	National	NO	YES	NO		
40	Degree of Imperviousness change	2012-2015	IMCC_1215_020m	20 m	National	NO	YES	NO		

No	Name of product	Rfr. year	Draft Abbreviation	Pixel size	Project ion	MMU	Re-projected	Re-sampled from 20m	Classified feature	Raster coding
	classified, 20 m, 2012-2015									

5. Thematic Accuracy

The general accuracy level of the HRL imperviousness products aimed to be in the order of 90 % (both, Producers and User's Accuracy). This accuracy should be reached for the pan-European mosaic. There will be three levels of accuracy assessment:

- a) SP reported as part of the delivery report,
- b) done on samples of the 20m products in European Projection by the ETC in the early production phase, and
- c) as a full independent validation of the full European mosaics after production.

Annex I: File naming convention

File naming for HRL products (raster and vector)

The proposed file naming convention will be applied both to raster and vector (no difference in file name, only “SWF” product is vector) HRLs and associated reports throughout the processing chain.

All letters are in small (not capital) letters, and no points (“.”) and/or minus (“-”) within file names.

The file naming is based on the following descriptors:

THEME	YEAR	RESOLUTION	EXTENT	EPSG	VERSION	

THEME:

- 3 letter abbreviation for main products (green)
- 4 letter abbreviation for change products (blue)
- 5 letter abbreviation for additional and expert products (orange)

REFERENCE YEAR

- 2012 and 2015 in four digits
- Change products in four digits (e.g. 0609)

RESOLUTION

- Four-digit (020m and 100m)

EXTENT

- 2-digit country code for country deliveries in national projection
- “eu” for all deliveries in European Projection (partial and full lot mosaics)

EPSG

- 5-digit EPSG code (geodetic parameter dataset code by the European Petroleum Survey Group)
- “03035” for the European LAEA projection

VERSION (only for final deliveries)

- 4-digit qualifier of the version number, starting with “V1_1” for a first full final version, and allowing to capture re-processing/calculation of small changes as (“V1_2”, “V1_3” etc.). In case of major changes a second version should be used (“V2_1”)

Table 6: File naming nomenclature

Descriptor	To be written as	Meaning	Comments
THEME	IMD	Imperviousness Degree	Three letter abbreviation for main lot 1 products
	IMC	Imperviousness Change	
	IMCC	Imperviousness Change Classified	
	IMDRP	Imperviousness Degree Reference Product (Vector data)	Reference product: Vector product with selected 100mx100m cells with density information
	IMDRG	Imperviousness Degree Reference Grid	Reference product: Imperviousness point grid
	NDVIG	Biophysical variables delivery	Scene-based result
	'tbd'	Other biophysical variables relevant for production	Scene-based result; abbreviation depending on index; tbd later
	TCD	Tree Cover Density	Three letter abbreviation for main lot 2 products
	DLT	Dominant Leaf Type	
	FTY	Forest Type	
	FADSL	Forest Additional Support Layer	
	DLTC	Dominant Leaf Type Change	
	TCDC	Tree Cover Density Change	
	TCDRP	Tree Cover Density Reference Product (Vector data)	Reference product: Vector product with selected 100mx100m cells with density information
	TCDRG	Tree Cover Density Reference Grid	Reference product: Tree cover point grid
	NDVIG	Biophysical variables delivery	Scene-based result
	'tbd'	Other biophysical variables relevant for production	Scene-based result; abbreviation depending on index; tbd later

Descriptor	To be written as	Meaning	Comments
	GRA	Grassland	Main lot 3 product
	GRAVP	Grassland Vegetation Probability	Additional lot 3 products
	PLOUG	Ploughing Indicator	
	WAW	Wetness and Water product	Main lot 4 product
	WWPRI	Wetness and Water Probability Index	Additional lot 4 product
	SWF	Small woody features	Main lot 5 product (vector dataset)
REFERENCE YEAR	2012	Reference year 2012 (+/- 1 year)	
	2015	Reference year 2015 (+/- 1 year)	
	0609	Change 2006-2009	Only for change products
	0912	Change 2009-2012	
	1215	Change 2012-2015	
	0612	Change 2006-2012	New change time period to be in line with CLC 6-years update cycle
RESOLUTION	020m	20m spatial (pixel) resolution	
	100m	100m spatial (pixel) resolution	
EXTENT	al	Albania	2-letter abbreviation for the country (in national projections), and "eu" for deliveries in European projection
	at	Austria	
	ba	Bosnia and Herzegovina	
	be	Belgium	
	bg	Bulgaria	
	ch	Switzerland	
	cy	Cyprus	
	cz	Czech Republic	
	de	Germany	
	dk	Denmark	
	ee	Estonia	
	es	Spain (including Andorra)	

Descriptor	To be written as	Meaning	Comments
	eu	European Projection mosaic deliver	
	fi	Finland	
	fr	France	
	gb	United Kingdom	
	gf	French Guiana	
	gp	Guadeloupe	
	gr	Greece	
	hr	Croatia	
	hu	Hungary	
	ie	Ireland	
	im	Isle of Man	
	is	Iceland	
	it	Italy	
	li	Liechtenstein	
	lt	Lithuania	
	lu	Luxembourg	
	lv	Latvia	
	me	Montenegro	
	mk	Macedonia, FYR of	
	mq	Martinique	
	mt	Malta	
	nl	Netherlands	
	no	Norway	
	pl	Poland	
	pt	Portugal	
	re	Réunion	
	ro	Romania	
	rs	Serbia	
	se	Sweden	
	si	Slovenia	
	sk	Slovakia	
	tr	Turkey	
	xk	Kosovo	
	yt	Mayotte	
EPSG	e.g. 03035	LAEA (European Projection)	5-digit EPSG code (geodetic parameter dataset code by the European Petroleum

Descriptor	To be written as	Meaning	Comments
			Survey Group) http://www.epsg-registry.org/
VERSION (only for final deliveries)	V1_1	First full final version	4-digit qualifier of the version number, starting with "V1_1" for a first full final version, and allowing to capture re-processing/calculation of small changes as ("V1_2", "V1_3" etc.). In case of major changes a second version should be used ("V2_1")
	V1_2	Re-delivery of first full final version with small changes	
	V2_1	Second full final version	
	etc	etc	

Annex II: File format specification

Raster products shall be delivered as GeoTIFF (*.tif) with world file (*.tfw), pyramids (*.ovr), attribute table (*.dbf) and statistics (*.aux.xml). Each product shall be accompanied with INSPIRE-compliant metadata in XML format and an INSPIRE Mapping Table as xls files. In addition, a PDF providing CRS information, including details of parameters used to transform to ETRS89 LAEA projection as in the following example from Hungary. The pdf should be named as follows: CRS_Information_Sheet_<country 2-letter ISO code>, e.g. CRS_Information_Sheet_BG.pdf.

CRS information sheets will be static and therefore will not have version numbers.

Table 7: CRS information sheet (sample)

National		
Datum		HD72 (EOV - Egységes Országos Vétületi rendszer)
	type	geodetic
	valid area	Hungary
Prime meridian		Greenwich
	longitude	0°
Ellipsoid		IUGG GRS 1967 (International 1967)
	semi major axis	6 378 160.0 m
	inverse flattening	298.2471674
Projection		Hotine Oblique Mercator (EOV proxy)
	latitude of projection center	47°08'39.817392"
	longitude of projection center	19°02'54.858408"
	azimuth of initial line	90°00'00"
	scale factor on initial line	0.99993
	false easting	650 000 m
	false northing	200 000 m
European		
Datum		ETRS89 (European Terrestrial Reference System 1989)
	type	geodetic
	valid area	Europe / EUREF
Prime meridian		Greenwich
	longitude	0°
Ellipsoid		GRS 80 (New International)
	semi major axis	6 378 137 m
	inverse flattening	298.257222101
Projection		Geographic (Ellipsoidal Coordinate System)
Datum shift parameters used		
Operation method		Bursa-Wolf (PositionVector)
	geocentric X translation	+52.684 m
	geocentric Y translation	-71.194 m
	geocentric Z translation	-13.975 m
	rotation X-axis -	0.312"
	rotation Y-axis -	0.1063"
	rotation Z-axis -	0.3729"
	correction of scale -	1.0191 ppm

Annex III: Detailed product tables

Table 8: Detailed specifications for primary 20m HR Imperviousness status layers.

Product
Degree of Imperviousness 2015 – IMD_2015_020m
Degree of Imperviousness, re-processed, 2012 – IMD-2012_020m
Degree of Imperviousness, re-processed, 2009 – IMD_2009_020m
Degree of Imperviousness, re-processed, 2006 – IMD_2006_020m
Geometric resolution
Pixel resolution 20m, grid to fully conform to the EEA Reference Grid.
Coordinate Reference System
European ETRS89 LAEA projection / national projections
Geometric accuracy (positioning scale)
Less than half a pixel. According to ortho-rectified satellite image base delivered by ESA ⁵
Thematic accuracy
<ul style="list-style-type: none"> Minimum 90% user's / producer's accuracy in general for status layers for a (derived) built-up/non built up map. Threshold to be applied in transforming imperviousness to built-up around 30% or less (tbd) Calibration accuracy: Minimum correlation, maximum deviation of the fitted trend line from main diagonal (to be defined later)
Data type
8bit unsigned Raster, compressed with LZW
Minimum mapping unit (MMU)
One pixel (20m)
Necessary attributes
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)
Raster coding (Thematic pixel values)
0: all non-impervious areas 1-100: imperviousness values 254: unclassifiable (no satellite image available, or clouds, shadows, or snow) 255: outside area
Metadata
XML metadata files are to be produced according to INSPIRE metadata standards
Delivery format
GeoTIFF

Table 9: Detailed specifications for the aggregated (100m) HR Imperviousness status layers

Product
Degree of Imperviousness 2015 – IMD2015_100m
Degree of Imperviousness, re-processed, 2012 – IMD2012_100m
Degree of Imperviousness, re-processed, 2009 – IMD2009_100m
Degree of Imperviousness, re-processed, 2006 – IMD2006_100m
Geometric resolution
Pixel resolution: 100m x 100m (aggregated) grid to fully conform to the EEA Reference Grid.
Coordinate Reference System
European ETRS89 LAEA projection / national projections
Geometric accuracy (positioning scale)
According to ortho-rectified satellite image base delivered by ESA ⁵
Thematic accuracy (in %)
<ul style="list-style-type: none"> • Minimum 90% user's / producer's accuracy in general for status layers • Calibration accuracy: Minimum correlation, maximum deviation of the fitted trend line from main diagonal (exact thresholds are to be defined later) • Additionally, the minimum accuracy of status layers is defined indirectly by the accuracy of derived IMD change products: 90% user's / producer's accuracy of derived IMD changes
Data type
8bit unsigned Raster, compressed with LZW
Minimum Mapping Unit (MMU)
One pixel (20m)
Necessary attributes
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)
Raster coding (Thematic pixel values)
0: all non-impervious areas
1-100: imperviousness values
254: unclassifiable (no satellite image available, or clouds, shadows, or snow)
255: outside area
Metadata
XML metadata files are to be produced according to INSPIRE metadata standards
Delivery format
GeoTIFF

⁵ As by the time of production start no spatial image reference database could be provided, a pan-European Sentinel-2 coverage was set up by the service providers as geometric reference dataset for HRL production

Table 10: Detailed specifications for HR Imperviousness change layers

Product
Degree of Imperviousness change, 2012-2015 - IMC_1215
Degree of Imperviousness change, re-processed, 2009-2012 - IMC_0912
Degree of Imperviousness change, re-processed, 2006-2009 - IMC_0609
Degree of Imperviousness change, 2006-2012 - IMC_0612
Geometric resolution
Pixel resolution: 20m x 20m and 100m x 100m (aggregated) grid to fully conform to the EEA Reference Grid.
Coordinate Reference System
European ETRS89 LAEA projection / national projections
Geometric accuracy (positioning scale)
According to ortho-rectified satellite image base delivered by ESA ⁵
Thematic accuracy (in %)
90% user's / producer's accuracy of derived IMD changes
Data type
8bit unsigned Raster, compressed with LZW
Minimum Mapping Unit (MMU)
One pixel (20m)
Necessary attributes
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)
Raster coding (Thematic pixel values)
0-99 decrease (0 = 100% decrease, 99 = 1% decrease) ⁶
100 stable built-up
101-200 increase (101 = 1% increase, 200 = 100% increase)
201 stable non built-up
254 unclassifiable
255 outside area
Metadata
XML metadata files are to be produced according to INSPIRE metadata standards
Delivery format
GeoTIFF

⁶ The raster coding for IMC considers sealing decreases with class codes of 0-99 (0 = 100% decrease, 99 = 1% decrease), and increases with class codes in the range of 101-200 increase (101 = 1% increase, 200 = 100% increase)

Table 11: Detailed specifications for the 20m classified imperviousness change products

Product
Degree of Imperviousness change classified, 20m, 2012-2015 - IMCC_1215_020m
Degree of Imperviousness change classified, 20m, 2009-2012 - IMCC_0912_020m
Degree of Imperviousness change classified, 20m, 2006-2009 - IMCC_0609_020m
Degree of Imperviousness change classified, 20m, 2006-2012 - IMCC_0612_020m
Geometric resolution
Pixel resolution 20m x 20m grid to fully conform to the EEA Reference Grid.
Coordinate Reference System
European ETRS89 LAEA projection / national projections
Geometric accuracy (positioning scale)
According to ortho-rectified satellite image base delivered by ESA ⁵
Thematic accuracy
90% user's / producer's accuracy of derived IMD changes
Data type
8bit unsigned Raster, compressed with LZW
Necessary attributes
Raster value, count, class name, area (in km ²), percentage (taking outside area not into account)
Raster coding (Thematic pixel values)
0: unchanged areas with imperviousness degree of 0 1: new cover - increased imperviousness density, zero IMD at first reference date 2: loss of cover - decreasing imperviousness density, zero IMD at second reference date 10: unchanged areas, IMD>0 at both reference date 11: increased imperviousness density, IMD>0 at both reference date 12: decreased imperviousness density, IMD>0 at both reference date 254: unclassifiable in any of parent status layers 255: outside area
Metadata
XML metadata files are to be produced according to INSPIRE metadata standards
Delivery format
GeoTIFF

Annex IV: NDVI Specifications

NDVI data format

Convert the NDVI to 8bit signed integer as follows:

- Rounding up NDVI values to the nearest value at 2 decimal places (i.e. NDVI of 0.118 -> 0.12, NDVI of 0.114 -> 0.11)
- Multiplication by 100
- Conversion to signed byte

To be delivered as GeoTIFF.

NDVI No Data Value

The float values of NDVI range from -1.0 to +1.0.

As 0.0 is a valid NDVI value, it is of no use as a no data value.

Instead, we will use 1.27.

Conversion to signed byte results in a no data value of 127.

NDVI filename

The NDVI filename convention is the name of the satellite scene that it was computed from, with a “_ndvi” concatenated to it before the image format extension.

e.g. <scene name>_ndvi.tif



Annex V: Color palette and attribute fields

With the HRL Imperviousness Status (IMD) and the Imperviousness Change (IMC) the same colour palette and attribute fields were provided as with previous HRL Imperviousness products. For the new Imperviousness Change Classified product (IMCC) a new colour palette and attribute fields were established.

Table 12: Colour palette and attributes of IMD layer

Class Code	Class Name	Red	Green	Blue	
0	all non-impervious areas	240	240	240	
1	1% imperviousness	255	237	195	
2-49	2% to 49% Imperviousness	colour shades in between			
50	50% imperviousness	175	74	51	
51-99	51% to 99% Imperviousness	colour shades in between			
100	100% imperviousness	113	12	2	
254	unclassifiable (no satellite image available, or clouds, shadows, or snow)	153	153	153	
255	outside area	0	0	0	

Table 132: Colour palette and attributes of IMC layer

Class Code	Class Name	Red	Green	Blue	
0	100% imperviousness decrease ⁷	3	102	0	
10	90% imperviousness decrease	12	114	0	
50	50% imperviousness decrease	63	178	0	
100	Sealed in both years (stable built-up)	178	178	178	
150	50% imperviousness increase	255	191	0	
200	100% imperviousness increase	255	0	0	

⁷ The raster coding for IMC considers sealing decreases with class codes of 0-99 (0 = 100% decrease, 99 = 100% increase), and increases with class codes in the range of 101-200 increase (101 = 1% increase, 200 = 100% increase)

201	Non-sealed in both years (stable non-built up)	240	240	240	
254	unclassifiable (no satellite image available, or clouds, shadows, or snow)	168	0	229	
255	outside area	0	0	0	

Table 13: Colour palette and attributes of IMCC layer

Class Code	Class Name	Red	Green	Blue	
0	unchanged areas (IMD=0%)	240	240	240	
1	new cover	255	0	0	
2	loss of cover	0	100	0	
10	unchanged areas (IMD>0% at both reference dates)	156	156	156	
11	increased IMD	255	191	0	
12	decreased IMD	64	178	0	
254	unclassifiable in any of parent status layers	255	0	255	
255	Outside area	0	0	0	

To all product deliveries both the GIS files specifying the colour palettes and a table listing the RGB values were provided in the following formats:

*.clr for GIS colour palettes

*.txt for other purpose