

# GMES Initial Operations / Copernicus Land monitoring services – Validation of products

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Validation Services for the geospatial products of the  
Copernicus land Continental and local components  
including in-situ data (lot 1)

**Open Call for Tenders - EEA/MDI/14/010**

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COPERNICUS/EEA.57056**

## HRL IMPERVIOUSNESS DEGREE 2015 VALIDATION REPORT



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## Executive Summary

This report covers the validation of the High Resolution layers (HRL) on Imperviousness (IMD) and Imperviousness change (IMC).

The IMD layer captures the spatial distribution of artificially sealed areas, including the level of sealing of the soil per area unit for a particular reference year. The level of sealed soil (imperviousness degree 1-100%) is produced using an automatic algorithm based on calibrated normalised difference vegetation index (NDVI). To date the IMD layer has been produced for four reference years; 2006, 2009, 2012 and 2015. Since the production of IMD layer in 2006 a time series of imperviousness has been produced. For each of the subsequent iterations the results have contained two products: a status layer for any reference year (e.g. IMD2012), as well as an imperviousness density change layer between reference years (e.g. IMC2012 is 2009 to 2012), and based on the already existing imperviousness product for that previous reference year. For the 2015 reference year the previous products were reprocessed to improve their calibration.

This report represents the analysis of the fully aggregated 100m spatial resolution IMD and IMC product deliveries for all reference years. The assessment of the IMD and IMC layers involved a review of the available datasets and the existing documentation prepared as part of the semantic checks performed during the production. The datasets and documented checks were compared against the specification prepared by the EEA and published in April 2018, as well as the original tender documents. This was a qualitative assessment reported in a pass / fail data quality list with additional comments from the validation team. A comprehensive assessment of the blind interpretation and a plausibility analysis are given to take into account input data limitations and better understand the cause of classification errors. These assessments included a quantitative analysis of the mapped imperviousness density and change against reference data in a stratified systematic sampling scheme.

The results in this report show that the HRL IMD product broadly meets most of the technical specifications, but the minimum thematic accuracy requirement of 90 %, based on a 30 % threshold of IMD values to represent urban areas, are not met in all cases. The IMD layer tends to underestimate imperviousness and there is variability from country to country or based on biogeographical regions. Improved results were obtained when using a plausibility approach which allowed for some variation in the reference data to account for acceptable mapped imperviousness. The outcome of the analysis of the scatterplots show that there is a strong relationship between the reference and map data. The variation between the sub-European regionalisations is a useful tool to explore the causes of the lower than anticipated thematic accuracies.

The results for the thematic accuracy of the changes fell short of the target requirement of 90 % at the pan-European level and for the majority of the regionalisations. Nevertheless, the change accuracy results are much improved compared to the previous assessment performed as part of the 2012 production. There were no clear patterns in the levels of accuracy or the relative occurrence of omissions and commissions across the regionalisations. The highly variable nature and the presence of extreme values would suggest relatively low levels of change which are not being adequately detected by the validation process at present.

It should be noted that any further in-depth analysis of the results should be made in the context of the reference and map data and consideration should be given to the regional differences when confirming classification anomalies. In this way further recommendations on how the products can be improved will be provided within a robust context.

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## List of Abbreviations

BRME	Biogeographical Regions Map of Europe
CLC	CORINE Land Cover
CRS	Coordinate reference system
DWH	Data warehouse
EEA	European Environment Agency
EO	Earth Observation
ETC ULS	European Topic Centre on Urban, Land and Soil systems
ETRS	European Terrestrial Reference System
EUREF	Regional Reference Frame Sub-Commission for Europe
FP7	7 <sup>th</sup> Framework Programme
FTS LM	Fast Track Service Land Monitoring
GDAL	Geospatial Data Abstraction Library
GIO	GMES Initial Operations
GMES	Global Monitoring for Environment and Security
GRS	Geodetic Reference System
HRL	High Resolution Layer
IMD	Imperviousness density
IMC	Imperviousness density change
INSPIRE	Infrastructure for Spatial Information in the European Community
LAEA	Lambert Azimuthal Equal-Area
LUCAS	Land Use/Cover Area frame Survey
MMU	Minimum Mapping Unit
MMW	Minimum Mapping Width
NDVI	Normalised Difference Vegetation Index
PSU	Primary Sample Unit
SSU	Secondary Sample Unit
TIFF	Tagged Image File Format

## 1. Validation Framework

The validation framework is defined by a comprehensive analysis of the product specifications to determine the criteria to be used for the validation exercise.

### 1.1. Products to be validated

Pan-European High Resolution Layers (HRL) provide information on specific land cover characteristics, and are complementary to land cover / land use mapping such as in the CORINE land cover (CLC) datasets. The HRLs are produced from 20 m resolution satellite imagery through a combination of automatic processing and interactive rule-based classification.

5 themes have been identified so far, corresponding with the main themes from CLC, i.e. the level of sealed soil (imperviousness), tree cover density and forest type, permanent grasslands, wetlands and water bodies. In the 2015 iteration the HRL for wetland and water layers were merged in to a single layer which recorded wetness and water. The natural grassland layer was also redefined for 2015 to become a new grassland baseline product based on 7-year time series and including all grasslands. A new product, based on VHR data, mapped small patchy and linear woody features.

Although produced and available for use at a high spatial resolution of 20 m, their constituent pixels were aggregated into 100 by 100 m grid cells for final products which were validated here.

The HRLs are pan-European wall to wall products which cover the EEA39 countries (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom plus Albania, Bosnia and Herzegovina, Kosovo, The former Yugoslav Republic of Macedonia, Montenegro and Serbia.).

The HRLs were produced in a centralized fashion involving the service industry through competitive market mechanisms on a layer by layer basis. In a decentralized approach the participating countries in the “Copernicus Local Land monitoring services: NRCs LC Copernicus supporting activities for the period 2017-2021” contracts were able to perform a verification of the HRLs if they wished, but that work will not be discussed here.

Built-up areas are characterized by the substitution of the original (semi-) natural land cover or water surface with an artificial, often impervious cover. These artificial surfaces are usually maintained over long periods of time. The Imperviousness HRL (IMD) thus captures the spatial distribution of artificially sealed areas, including the level of sealing of the soil per area unit. The level of sealed soil (imperviousness degree 1-100%) is produced using an automatic algorithm based on calibrated normalised difference vegetation index (NDVI).

The IMD layer was the first HRL to be produced for 2006. However, at the time it was described as a “soil sealing database for Europe” and delivered as part of the GMES (Global Monitoring for Environment and Security, former name of Copernicus) Fast Track Service on Land Monitoring (Land FTS LM). It was produced during 2006-2008 from multi-sensor and bi-temporal, orthorectified satellite imagery, IMAGE2006, the same as the CORINE Land Cover 2006 update. The production of IMD2006 covering 38 European countries (32 EEA Member States and 6 West-Balkan countries) and was implemented in two phases:

- an initial soil sealing product based on the EEA specification, and
- a soil sealing enhancement product based on evaluation of the initial product by some Member States.

The production approach used an automatic algorithm based on calibrated NDVI. The main deliverable was a raster dataset of continuous degree of soil sealing ranging from 0 – 100 % in full spatial resolution (20 m x 20 m) with the associated metadata. A derived product, a raster dataset of continuous degree of soil sealing ranging from 0 - 100% in aggregated spatial resolution (100 m x 100 m) in European projection was validated.

Since the production of IMD2006 a time series of imperviousness has been produced for reference years 2009, under the FP7 Geoland2 project, and 2012, under the GMES Initial Operations (GIO). For each of these iterations

the results contained two products: a status layer for any reference year (e.g. IMD2012), as well as an imperviousness density change layer between reference years (e.g. IMC2009to2012) based on the already existing imperviousness product for that previous reference year. It is worth noting that there have been revisions to the previous year's IMD products during updating and the IMC time series has been reworked.

The latest imperviousness update for 2015 was also produced as part of the Copernicus Land Monitoring Services and was available with free and open access (see <http://land.copernicus.eu/>).

When considering all the IMD products a density threshold of 30% has been used to derive binary built-up mask layer from the imperviousness values. This was not intended to be a separate product, but instead was calculated for the verification / validation process only, because density products cannot be verified.

For 2015, all the previous IMD and IMC layers were reworked. The derivation of Imperviousness 2006-2009-2012 consisted of two separate procedures, the reprocessing and the re-analysis of the historical layers. The methodologies applied for both the reprocessing, and re-analysis of all existing density products, assured a properly calibrated HRL Imperviousness time-series.

HRL products should be validated as integrated Pan-European mosaics at 100m pixel size. The following products should be validated:

- Degree of Imperviousness 2006, 2009, 2012 and 2015, 100m x 100m, European projection, LAEA
- Imperviousness density change between 2006 & 2009, 2009 & 2012 and 2012 & 2015, 100m x 100m, European projection, LAEA

## 1.2. Validation Criteria

For the IMD and IMC layers the main criteria selected for the validation will be:

- Completeness, the amount of omission and commission.
- Logical consistency, the adherence to formats, conventions and conceptual aspects.
- Thematic accuracy, the correspondence with reference data.
- Temporal quality, the alignment of the results with the reference year.
- Usability
- Metadata, the presence of sufficient metadata to describe the product.

Other validations criteria are either not applicable (topological consistency is not relevant for a raster dataset) or being dealt with by other aspects of the project (positional accuracy is an assessment of the image data).

### 1.2.1. IMD2006, IMD2009, IMD2012, IMD2015

The validation of the Imperviousness Degree Layer for 2006 through 2015 was done at two levels:

- A scatterplot of the density values extracted from the sample units for both the reference and map data for each reference year was made with a view to assess the correlation between reference and map values and identify any systematic bias (slope and intercept of the regression line significantly different for 1 and 0 respectively).
- A threshold was applied to the density values for reference and map data to produce binary attributes of built-up for both the reference and map data layers. For IMD, the threshold was set to 30 % with density values lower than 30 % classified as 0 (non-built-up) and density values greater than or equal to 30 % classified as 1 (built-up). The minimum acceptable thematic accuracy of 90 % should be reached for both omission and commission errors for class 1 (built-up).

## 1.2.2. IMCC2006-2009, IMCC2009-2012, IMCC2012-2015

The validation of the Imperviousness Degree Change Layer for 2015 was also done at two levels:

- A scatterplot of the density values extracted from the sample units for both the reference and map data was made with a view to assess the correlation between reference and map values and identify any systematic bias (slope and intercept of the regression line significantly different for 1 and 0 respectively).
- Although there was no specific threshold set for the imperviousness density change products, analyses were performed with thresholds based on the 100 m aggregation method and the urban layer definition applied to the density values for reference and map data to produce 6 change classes for both the reference and map data layers (Table 1-1).

Table 1-1: Thresholds used for the correspondence analysis of IMC2006-09, IMC2009-12 and IMC2012-15.

Class	Name	IMD T <sub>0</sub> (%)	Ref T <sub>0</sub> (%)	IMC (Difference T <sub>1</sub> - T <sub>0</sub> )
1	No change			-29 to +29
2	Decreased sealing			< -80
3	Increased sealing new urban	< 30		> 29
4	Increased sealing existing urban	> 29		> 29
5	T <sub>0</sub> omission	< 30	> 29	
6	T <sub>0</sub> commission	> 29	< 30	

## 2. Validation approach

The validation approach provides guidance on how the products will be validated by defining suitable indicators or metrics.

Detailed completeness and logical consistency checks are performed as part of the semantic checks undertaken by ETC ULS for most products. Therefore, the aim of this validation exercise is not to repeat these, but to review the existing documentation and perform additional checks if deemed necessary.

The quality assessment is performed according to INSPIRE Data Specifications. The data quality elements considered are: (i) Completeness, (ii) Logical Consistency, (iv) Thematic Accuracy, (v) Temporal quality and (vi) Usability. Each of these criteria forms a section in the Validation Check list in section 3.

Logical consistency checks do not consist in a duplication of Semantic checks, but are performed to identify missing information if relevant.

Thematic accuracy will represent the bulk of the work undertaken as part of this validation exercise.

The validation exercise will refer to the technical details of the IMD product as set out in “Copernicus Land Monitoring Service – High Resolution Layer Imperviousness: Product Specifications Document”, Creation date “2016-03-10” and Identifier “This is version 1 of 2018-04-06.” available on the land.copernicus.eu site 23/11/2018. 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.

### 2.1. Completeness

**Description:** For land cover and land use products (both raster & vector), the notion of completeness in INSPIRE provides an indication of omission and commission areas. Commission - excess data present in the dataset, as described relative to the scope. Omission - data absent from the dataset, as described relative to the scope. This operation will be applied at the dataset level, rather than spatial object, and related to area extent. It can also include attributes and whether they are set etc., but this is actually covered by further checks below.

**Indicators:** For the completeness of the IMD / IMC the proportion of excess data beyond the required extent is used for commission errors and the proportion of missing data within the required extent is used to represent the omission errors.

However, the total extent referred to is not clearly defined as land area or whether there are territorial buffers that reach out to sea when finalising products. For delineation of the production area (EEA39) a combination of the EuroBoundaryMap v11 (EBM) and GISCO boundaries was used for the 20 m HRL Imperviousness 2015 status and all change products. 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.

This check was performed by visually checking the extent of the product against the known extents of the EEA-39 countries.

## 2.2. Logical consistency

Logical consistency evaluates the degree of adherence to logical rules of data structure, attribution and relationships. In the INSPIRE Data Specifications, logical consistency comprises four sub-elements described hereafter: conceptual consistency, domain consistency, format consistency and topological consistency. As the IMD and IMC products are in raster format the topological consistency is not relevant.

### 2.2.1. Conceptual consistency

**Description:** Conceptual consistency relates to the data structure and follows the data specifications in terms of data model and relationships. It is also related to the adherence to the rules of the conceptual schema.

**Indicators:** For the IMD and IMC layers the properties of conceptual consistency are mainly defined for the 20 m products, with the inference that the same are applied to the versions aggregated to 100 m spatial resolution. The properties appropriate to raster data can be defined as:

- Type of feature used. In the case of raster dataset, the features are pixels. The raster bit depth is defined to encompass the required number of numeric values / thematic codes. For the IMD / IMC the raster format is proposed but no specific depth is set. However, the range of required numeric values / thematic codes would suggest unsigned 8-bit data.
- Minimum Mapping Unit (MMU). This is the minimum size a feature may have within the dataset. In the case of raster datasets this is the spatial resolution or grid cell size. For the IMD / IMC the spatial resolution should be 100 m.
- Coordinate Reference System (CRS). A coordinate-based local, regional or global system used to locate geographical entities and defines a specific map projection. CRS will be dealt with in detail later, but for the IMD / IMC it is the European LAEA.

### 2.2.2. Domain consistency

**Description:** Domain consistency in raster datasets relates to the various range structures for bands and attributes, e.g. number of available bands with their names, the units of measure, the data type and the null value used. Checking domain consistency involves assessing the numbers of bands and the detection of attribute / pixel values that are outside the pre-defined ranges or sets of values. For raster data such as IMD / IMC, the correct encoding of data is checked.

**Indicator:** The domain consistency properties are divided into two main groups. The overall data structure of the raster file and the valid values for the pixels.

The data structure for the HRLs should be a single band raster of type unsigned 8-bit.

The valid values for the pixels will be different between the IMD and IMC datasets as they are representing different characteristics of the surface.

IMD:

- 0: all non-impervious areas
- 1-100: imperviousness values
- 254: unclassifiable (no satellite image available, or clouds, shadows, or snow)
- 255: outside area

IMC:

- 0-99: decreased imperviousness density (0 = 100 % decrease, 10 = 95 % decrease etc.)
- 100: unchanged areas with a recorded imperviousness degree in both IMD layers of 1-100
- 101-200: increased imperviousness density (200 = 100 % increase, etc.)
- 201: unchanged areas with imperviousness degrees of 0
- 254: unclassifiable (no satellite image available, or clouds, shadows, or snow)
- 255: outside area

IMCC:

- 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

### 2.2.3. Format consistency

**Description:** Format consistency includes the consideration of file formats, file or attribute names or attribute types. In addition, for raster data the pixel depth is also considered here. File format, schema, naming conventions etc. Degree to which data is stored in accordance with the physical structure of the dataset, as described by the scope.

**Indicators:** For the IMD / IMC layers which are raster-based products plus documentation, only the following format consistency properties need to be check:

- File format conformance
  - Raster products shall be delivered as GeoTIFF (\*.tif) with world file (\*.tfw), pyramids (\*.ovr), attribute table (\*.dbf) and statistics (\*.aux.xml).
  - Compression: LZW
  - Each product shall be accompanied with INSPIRE compliant metadata in XML format and an INSPIRE Mapping Table as XLS files.
  - 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. See Table 6 in specification document.
  - CRS information sheets will be static and therefore will not have version numbers.

- File name conformance

A set of filename conventions were established in the product specifications, but these referred only to the country level products and associated reports. The conventions are based on the following descriptors:

- 'theme' – the particular HRL as a 3-letter abbreviation of processing stage, e.g. 'imd' for Imperviousness Degree and 'imc' for Imperviousness Change.
- 'year' – four digits e.g. 2012 for the IMD layer and 0912 for the IMC layer.
- 'resolution' – a four-character abbreviation (020m and 100m).
- 'extent' - either a 2-letter country code for country deliveries in national projection or "eu" for all deliveries in European Projection (partial and full lot mosaics).
- 'EPSG' – a 5-digit EPSG projection code (geodetic parameter dataset code by the European Petroleum Survey Group), e.g. "03035" for the European LAEA projection.
- 'version' (only for final deliveries) – 4 character 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").

The file name format should therefore be:

*<theme>\_<year>\_<resolution>\_<extent>\_<EPSG>\_<version>*

As an example, the imperviousness layer for 2015 in LAEA projection and 100 m spatial resolution should be supplied as follows:

*imd\_2015\_100m\_eu\_03035\_V1\_1.tif*

## 2.2.4. Additional logical consistency checks

There are further logical consistency checks that should be made to make sure the data confirms with the specifications to allow ease of use.

- **Labelling or symbology:** The conformity of a layer with the symbology or style given in the product specifications should be checked. The EEA provided colour tables to be built into raster datasets for all the HRLs.
- **Map projection:** The conformity of the map projection parameters is also checked. The selected projection for the HRL data is the LAEA-ERTS89 (Table 2-1).

Table 2-1: Map projection details for LAEA-ERTS89.

European		
Datum	Name	ETRS89 (European Terrestrial Reference System 1989)
	Type	geodetic
	Valid area	Europe / EUREF
Prime meridian	Name	Greenwich
	Longitude	0°
Ellipsoid	Name	GRS 80 (New International)
	Semi major axis	6 378 137 m
	Inverse flattening	298.257222101
Projection		Geographic (Ellipsoidal Coordinate System)

## 2.3. Positional Accuracy

The positional accuracy of the products is being addressed through the source EO image data and will only be considered here if unusual issues arise.

## 2.4. Thematic Accuracy

The thematic accuracy quantifies the relationship of the product to a set of reference data. The reference data can come from many sources and could be a binary mask, categorical set or continuous variables.

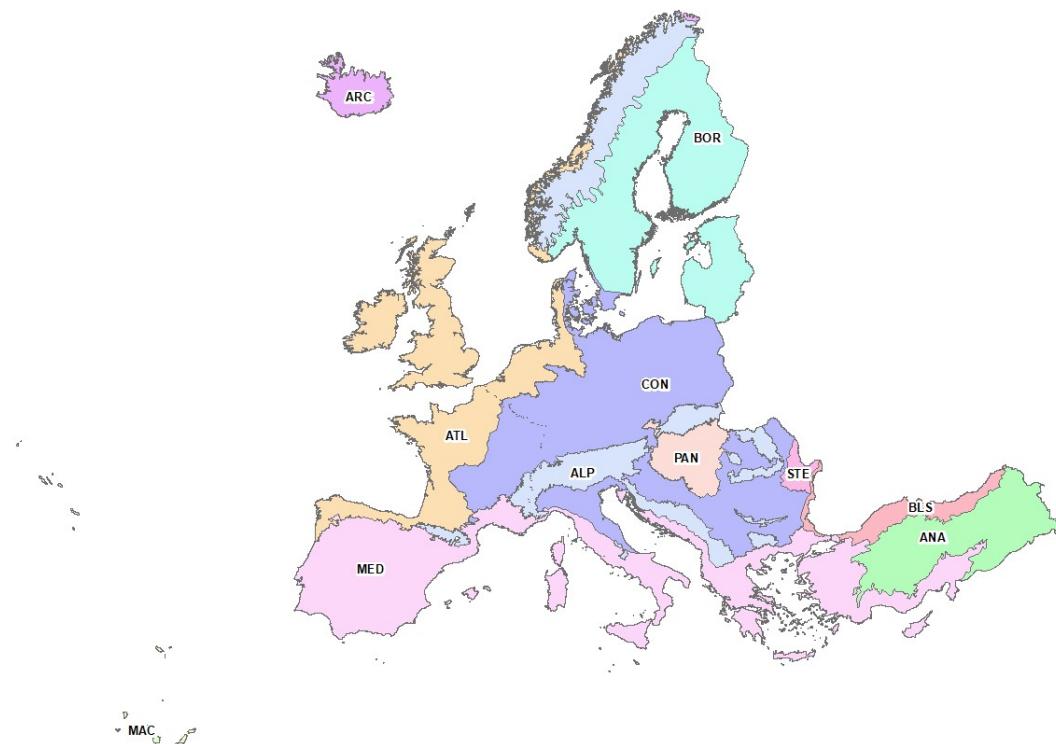
The thematic accuracy requirement is set relative to an urban area mask. A threshold of 30 % should be applied to transform imperviousness to built-up. A minimum thematic accuracy requirement was set at 90 % overall accuracy target, as well as 90 % for producer's accuracy (commission) and 90% for user's accuracy (omission).

### 2.4.1. Level of reporting

Regarding the level of reporting for the internal validation, results will be provided at different levels of aggregation. So, the accuracy of the products will be reported at EEA39 level and at more disaggregated scales. The analysis at disaggregated levels will contribute to assess regional differences, if any, and the nature of these differences.

The internal validation needs to find a compromise between the number of sample units and representativeness of the results at sub-European level. Therefore, the envisaged levels of reporting are:

1. Pan-European.
2. Biogeographical regions 2016 (Figure 2-1).



*Figure 2-1. Level of reporting accordingly to the biogeographical regions*

3. Country or aggregated countries as described in the previous Specific Contracts in 23 main countries or groups of countries (including French DOMs). Countries < 90,000 km<sup>2</sup> shall be grouped into contiguous groups of countries > 90,000km<sup>2</sup> as much as possible (Figure 2-2).

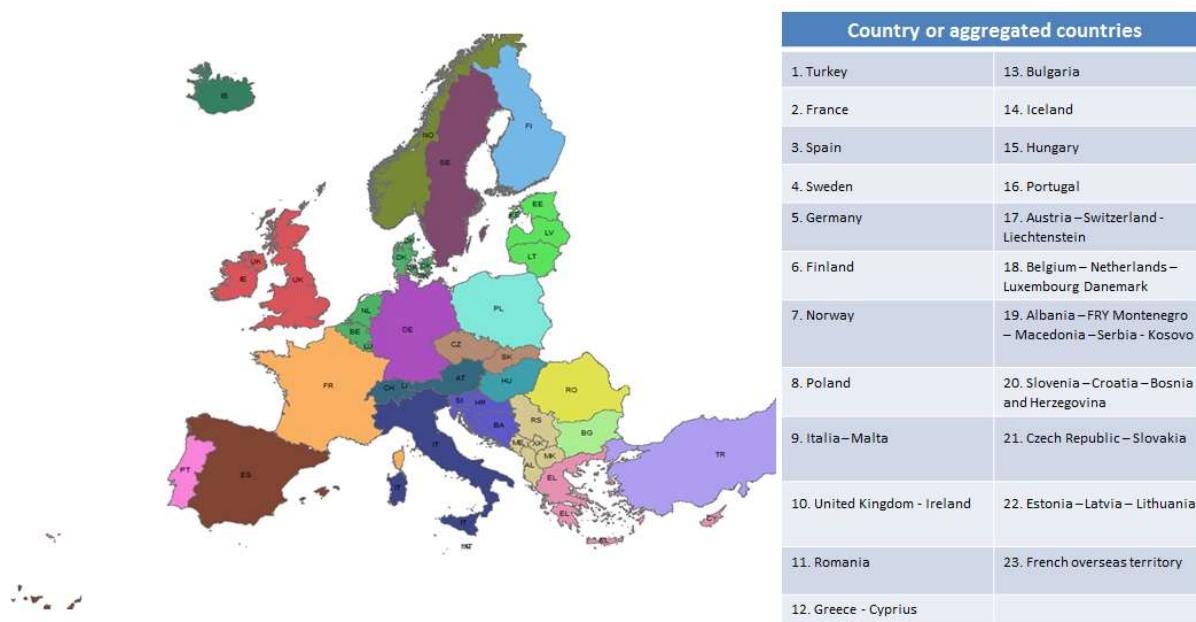


Figure 2-2. Level of reporting accordingly to the country or aggregated countries

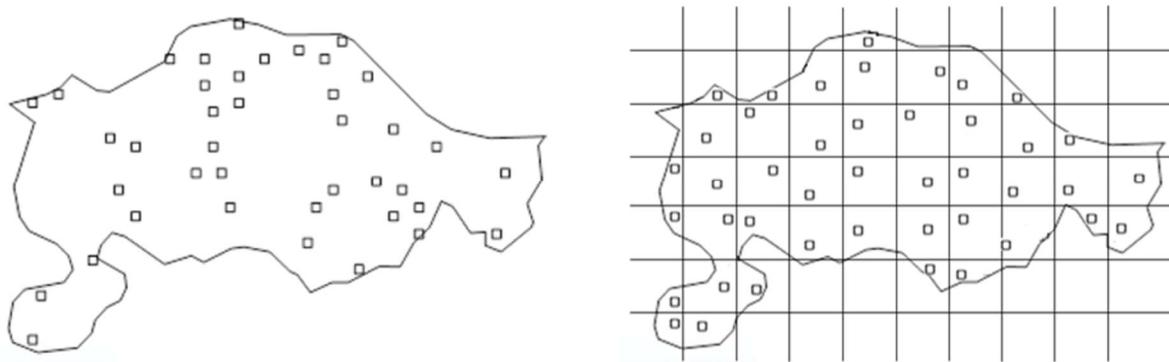
## 2.4.2. Stratification and sample design

### 2.4.2.1. Overview

The stratification and the sampling design primarily consists in selecting an appropriate sampling frame and sampling unit. The sampling units can either be “defined on a cartographic representation of the surveyed territory” (Gallego, 2004), in which case it is an area frame, or on a list of the features. According to (Gallego, 2004), area frames give a better representation of the population as the spatial dimension is kept.

In an area frame, sample units can be points, lines (often referred to as transects) or areas (often referred to as segments, described by Gallego, 1995). The first step is to define the geographical area for which the accuracy assessment is to be reported and the type of sample units. For the majority of cases, point samples will be used, but areas or segments may be used in specific cases such as when not only thematic accuracy needs to be reported, but also the geometry of mapped objects. Points are considered as the most appropriate unit for our purpose. Polygons have also the drawback of being specific to a single map. In case of changes, the sample may not be adapted anymore.

Sampling design refers to the protocol whereby the samples are selected. A probability sampling design is preferred for its objectivity. “Simple random, stratified random, clustered random and systematics designs are all examples of probability sampling designs” (Stehman *et al.*, 1998). Even though a simple random design is easy to implement, its main drawback is that some portions of the population may not be adequately sampled. Cluster sampling is often used to reduce the costs of the collection of reference data but does not resolve geographic distribution problems. A systematic approach would solve this problem, yet it is not appropriate if the map contains cyclic patterns. A stratified approach consists in allocating a pre-defined number of samples per land-cover class. As explained in (Stehman *et al.*, 1998), stratification ensures that each class is represented.

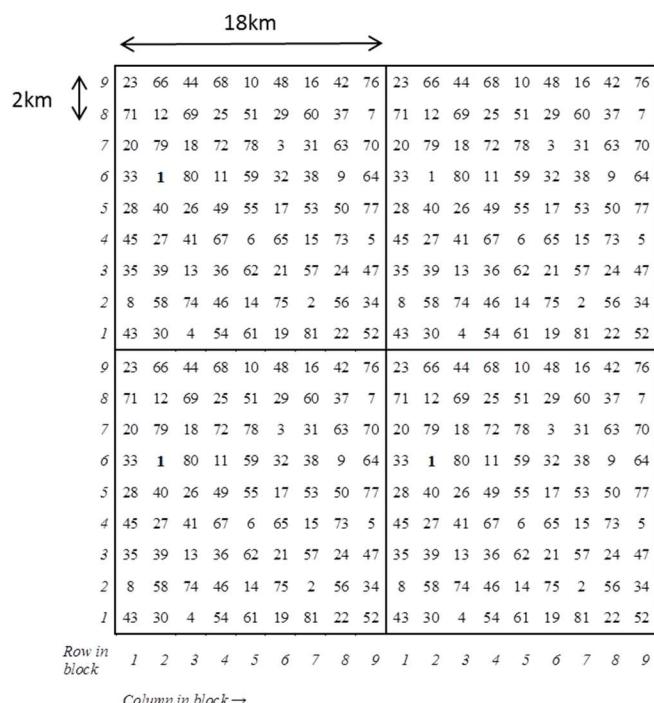


**Figure 2-3. Simple random (left) and random systematic (right) sampling designs**

The sampling and stratification design presented below is applicable to all HRL Imperviousness products including change products.

The validation approach of the previous Specific Contracts was adopted. It is based on a selected sample design for thematic accuracy assessment and combines systematic and stratified approaches and benefits from the advantages of both of them. It is based on the LUCAS (Land Use/Cover Area frame statistical Survey) sampling approach. LUCAS corresponds to a grid of approximatively 1,100,000 points throughout the European Union where land cover or land use type is observed. Using LUCAS points ensures traceability and coherence between the different layers.

LUCAS points are located every 2 km on a regular grid, as illustrated below. A set of 81 points located on an 18x18 km square constitutes a group in which every point is associated with a number comprised between 1 and 81 (the numbers do not follow each other spatially). The same pattern with the same numbers allocation is repeated all over the grid. A replicate refers to the points with the same number selected on the whole LUCAS grid.



**Figure 2-4. LUCAS points located on a regular grid**

At first, the number of samples to allocate to each stratum (or thematic class) is calculated as a function of their area. In this manner the sampling design is not only systematic but also stratified. The number of sample units per stratum is to be defined to ensure proper level of precision at reporting level.

The determination of the number of sample units also considers the number of thematic classes.

It is possible to estimate a suitable sample size for each stratum based on the expected acceptable error rate.

The standard error of the error rate can be calculated as follows:  $\sigma_h = \sqrt{\frac{p_h(1-p_h)}{n_h}}$  (1) where  $n_h$  is the sample size for stratum  $h$  and  $p_h$  is the expected error rate. This can be reworked to express the sample size  $n_h$  as a function of  $p_h$  and desired standard error  $\sigma_h$ :  $n_h = \frac{p_h(1-p_h)}{\sigma_h^2}$ . (2)

From Figure 2-5 it can be seen that for an expected 50% error rate, within a stratum, 100 sample units would be required to guarantee a standard error of 5%, whereas the number of samples would need to be increased by a factor of four if the accepted standard deviation is divided by a factor of 2. On the other hand, if the expected error rate is 15%, only 51 samples would be necessary with a 5% standard error. A similar approach was adopted to determine the sample size for assessing the accuracy of CLC2006 and CLC2000-2006 changes (Büttner *et al.* 2012). This works well to assess commission errors, the definition of an appropriate number of sample units for omission errors is more difficult because it depends on the expected area of the theme to be mapped.

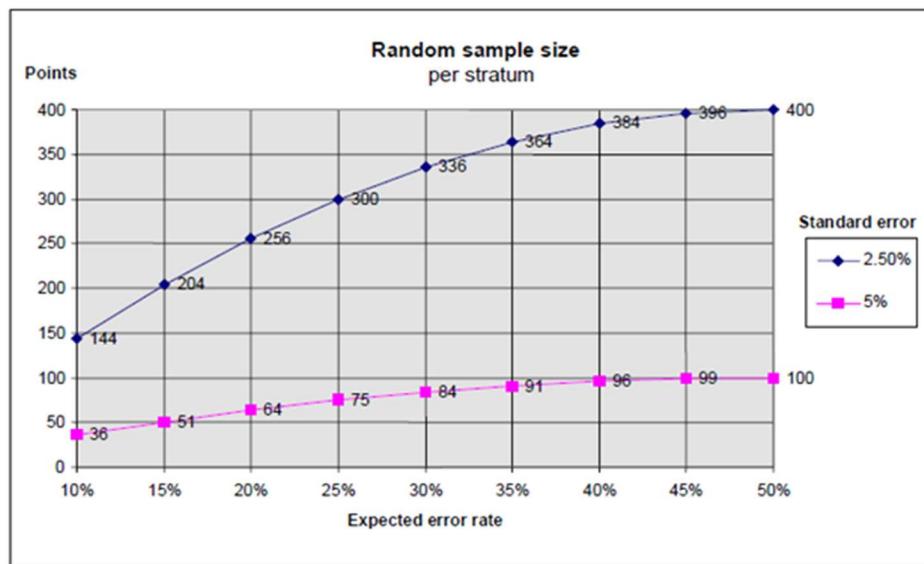


Figure 2-5. Number of sample points as a function of the expected error rate for two accepted standard error values (after Wack *et al.* 2012)

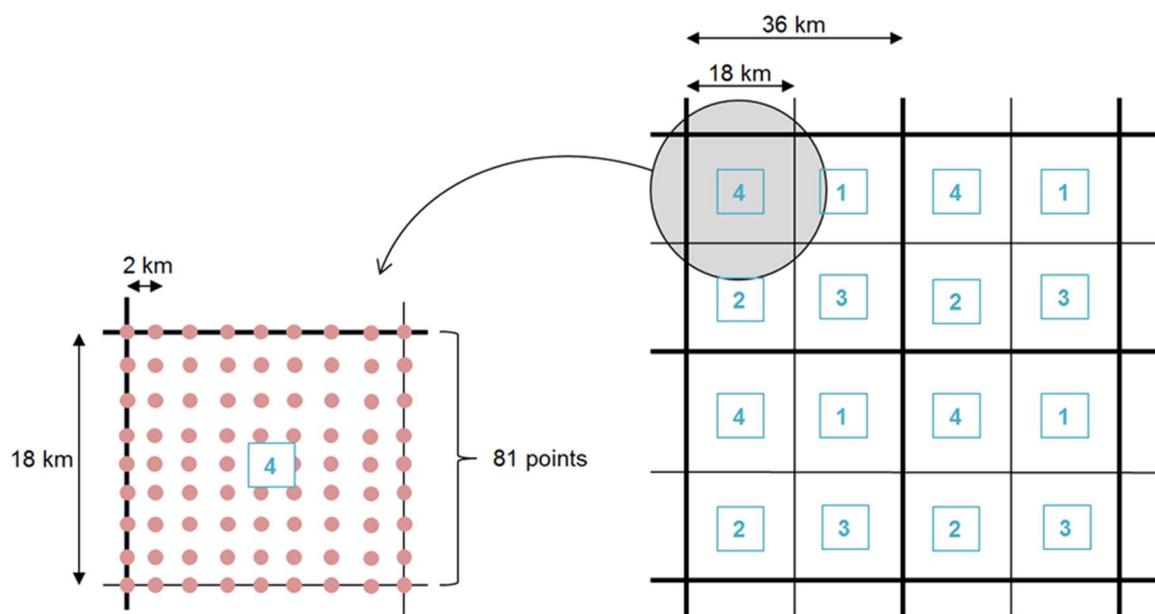
When using stratified sampling, the main issue to maximise the efficiency of the stratification (maximise the level of precision) is to optimize the sample allocation per strata. A simple way is the use of equal allocation. Alternatively, the Neyman allocation algorithm is also often used for that purpose:

$$n_h = n * (N_h * \sigma_h) / [\Sigma (N_i * \sigma_i)], \quad (3)$$

where  $n_h$  is the sample size for stratum  $h$ ,  $n$  is the total sample size,  $N_h$  is the population size for stratum  $h$ , and  $\sigma_h$  is the standard deviation of stratum  $h$ . According to Stehman (2012), Neyman optimal allocation should be preferred for estimating area of change as well as overall accuracy, whereas equal allocation is effective for estimating user's accuracy.

The number of replicates to be selected for a stratum depends on its area and the number of LUCAS points intersecting the stratum.

For thematic classes covering a large proportion of the study area, 1 replicate may already exceed the defined number of samples for this class. To solve this problem, replicates are split into four sub-replicates, as illustrated by the blue numbers in the Figure below.



*Figure 2-6. Replicates and sub-replicates used on LUCAS grid*

The opposite problem is encountered for land cover classes covering a small proportion of the study area: even by selecting 81 replicates (the maximum number), the intersecting area between the stratum and LUCAS points is too small to reach the required number of samples. Therefore, LUCAS grid could be densified by creating one point every 200 m.

#### 2.4.2.2. Stratification approach

For the IMD/IMC products, a stratification is applied based on a series of omission/commission strata at pan-European level.

The number of sample units called **Primary Sampling Units (PSUs)** per stratum based on LUCAS and densified LUCAS grid should be such to ensure a sufficient level of precision at reporting level. Priority is given to strata which are known to be difficult to map: i.e. changes and difficult classes. That is why different sampling intensities can be applied to focus on strata for which there is a higher probability that errors will be found.

The level stratification based on omission/commission strata for the Imperviousness Status and Change layers is defined as follows:

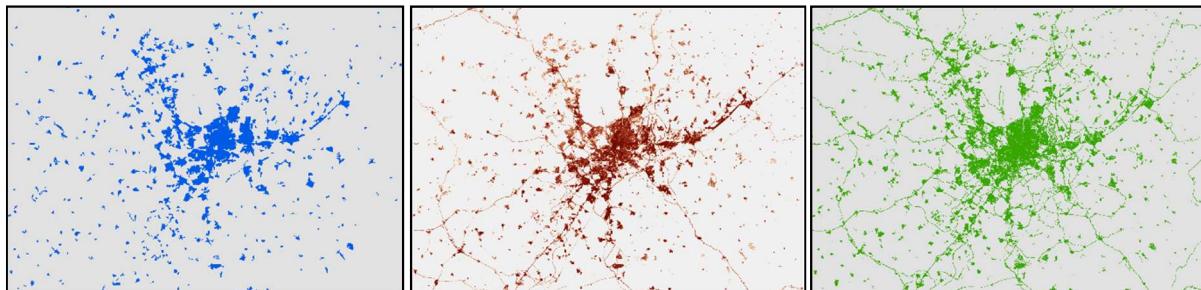
- Commission: Imperviousness Degree 1-100% in 2015
- Omission High Probability: Imperviousness Degree 0% in 2015 and Open Street Map & CLC “impervious classes”
- Omission Low Probability: Rest of the area
- Commission Change: all changes 2006-2009, 2009-2012 & 2012-2015 [gain, loss, increased and decreased]

Regarding the change layers, PSUs will be selected within the 4 different change strata (urban increase, urban decrease, urban loss, urban gain) in order to ensure to have sample units within each class of interest. The selection of the PSUs in these strata will also take into account the sample units drawn for the omission and commission strata to avoid duplicates.

For both status and change layers, CLC artificial classes and Open Street Map road network are used and converted to a pseudo artificial layer. Relevant OSM road types are selected and rasterized to 100m (for example, abandoned, construction, cycleway, path, planned, trail, track... are removed) to obtain the artificial areas. Using a relevant selection of OSM road types tend to lead to a better spatialization of artificial and impervious areas.

CLC impervious classes are defined as follows based on CLC2012:

- 1.1.1 = continuous urban fabric
- 1.1.2 = discontinuous urban fabric
- 1.2.1 = industrial, commercial areas
- 1.2.3 = ports
- 1.2.4 = airports



*Figure 2-7: Comparison HRL 2015 (red) vs CLC 2012 (blue) and OSM (green)*

The validation exercise covers the whole study area in order to be valid (e.g. use of low and high probability omission strata for HRL with low sampling intensity in low probability stratum).

Each PSU corresponds to one HRL aggregated pixel (100m). Each PSU is then associated to secondary sampling units (SSUs) corresponding to a 5x5 grid with 20m between each SSU (*Figure 2-8*). The idea is that each SSU can then be associated with the corresponding HRL 20m layer pixel. This approach is suitable both for assessing the 2015 imperviousness density status values as well as the change values. Each PSU will be interpreted based on VHR image data for each reference date (2006, 2009, 2012 and 2015) and change values will then be derived from the actual change layers allowing the assessment of the accuracy.



*Figure 2-8: Example of SSUs organised in a 5x5 20m grid*

Sampling units will be different for each layer due to different stratification approaches, but some sample locations will be shared thanks to using LUCAS as the basis for selecting sample units

There was a total of 22,777 sample units selected for this specific contract (Table 2-2):

*Table 2-2: Distribution of sample units per main strata and substrata*

	Strata	Number of sample units
Commission	Status 2015	3,959
	Change 0609	1,590
	Change 0912	1,579
	Change 1215	1,575
	Change 0609 & Change 0912	3
	Change 0609 & Change 1215	7
	Change 0912 & Change 1215	18
Omission	High Probability	1,019
	Low Probability	13,027
<b>Total</b>		<b>22,777</b>

To ensure that unequal inclusion probabilities are accounted for in the construction of the error matrix, weights are applied to each stratum as shown in (Table 2-3) following the formula presented at the beginning of section 2.4.4.

*Table 2-3: Weight factor to be applied to each stratum and substratum for constructing confusion matrices*

	Strata	Number of sample units
Commission	Status 2015	0.3692896
	Change 0609	0.0061658
	Change 0912	0.0076993
	Change 1215	0.0047862
	Change 0609 & Change 0912	0.0091644
	Change 0609 & Change 1215	0.0059219
	Change 0912 & Change 1215	0.0056818
Omission	High Probability	0.3691531
	Low Probability	1.6050622

The sample units were provided to the bulk interpretation team as separate shapefiles in which all the information on strata was removed to ensure the independence of the interpretation.

## 2.4.3. Response Design

### 2.4.3.1. Overview

The LUCAS points were re-interpreted based on available in situ and reference data, but the LUCAS thematic information is not used directly during the process.

The response design for most data sets being validated during this project was based on the interpretation of thematic classes or surface characteristics (e.g. soil sealing) at the SSU point level taking into account the details of the product specifications (MMU, MMW, class definitions, etc. ...). The interpretation was based on a combination of available in situ data, for example, the HRL and CLC2012 validation could use the VHR mosaic alongside the imagery used in production and virtual globes datasets.

A double blind approach was adopted as the initial process to guarantee the complete independence of the validation data from the map products. This may underestimate their accuracy where SSU points are uncertain. This was resolved by the plausibility approach for which the interpreter checks the map value to assess whether it can be considered correct or not, within the frame of accepted product specifications. Also, density values may be adjusted based on experience of known uncertainties to allow a more realistic comparison.

The interpretation of each PSU at a particular point in time is based on the assessment (sealed or unsealed) of 5 x 5 grid of SSU points to derive a density value of soil sealing (imperviousness) at the PSU level (*Figure 2-8*). The values are thus represented by percentage values in 4% steps from 0 – 100%. The process is then repeated for each time point.

The datasets against which the interpretation is performed are divided in two main groups, guiding data and reference data.

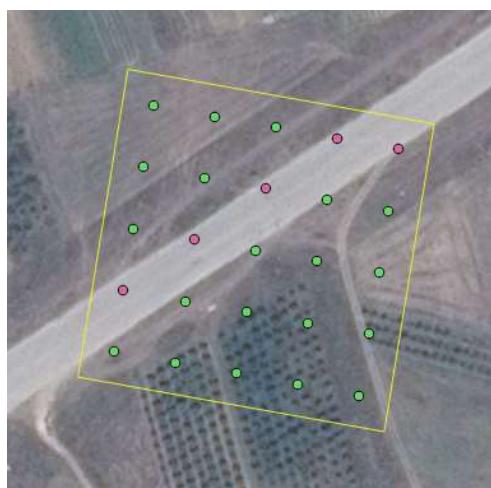
The guiding data were used in the production of the IMD and IMC layers and are hosted by the EEA as web services. The available guiding data were:

- 2015 VHR IMAGE 20 m dataset (not used for original production)
- 2012 HRIMC1 25 m dataset (not used for original production)
- 2009 HRIMC1 20 m dataset (used during production)
- 2006 HRIMC1 20 m dataset (known issue: Shift in relation to 2012 & 2009 datasets)

The reference data were to provide more spatial detail and strong landscape context to the assessment. The available reference data were:

- Bing maps image / cartography layer
- Open Street map data
- GoogleEarth image / cartography data
- Further in-situ data

The interpretation process was controlled, and the results recorded by the selected sample locations. For each location there were two vector layers. The sample points, or PSU, were represented by a 100 m by 100 m rectangle with a centre point at the selected location and the grid points, or SSU, were represented by a set of points on a 5 x 5 grid with 20 m spacing within each PSU (*Figure 2-9*). Each dataset contained a set of attributes to both define the characteristics of the sample point, PSU or SSU, and the results of the assessment.



**Figure 2-9: An example of the PSU (yellow square) and the SSU (green and red dots) for one sample location based on a LUCAS point.**

For the IMD / IMC the assessment process was applied to approximately 23,000 PSUs each of which contained 25 SSU making in excess of 550,000 total interpretations per time point. To perform an internal quality check 10% of the assessments undertaken by the bulk interpretation team were repeated by an independent team.

For each PSU and its constituent SSUs the following process was followed to complete the assessment.

At the PSU level the guiding data was screened for clouds and cloud shadows and a note was made in the comment attributes when no useable data was available for a reference year. The presence of any spatial shifts either between the guiding datasets or against reference datasets were also noted.

At the SSU level within each PSU the first step was to assess the guiding data in the context of the available reference data to understand the relationship between the guiding data and the reference data. Then, using the guiding data for 2015 in the context of the reference data, an assessment was made whether the surface at each SSU was sealed or unsealed. If the surface was sealed a value of 1 was assigned to the CODE15 attribute on the SSU point feature. If the surface was unsealed a check was made to ensure that the CODE15 attribute for SSUs point feature was set to 0. If necessary, the UNCERTAIN and COMMENT attributes were used to record SSUs where the coding of sealing was unclear or certain issues occurred.

Next, using the guiding data for 2006, 2009 and 2012 in the context of the reference data, an assessment was made whether the status of the sealing at each of the SSU point features had changed between 2006, 2009 and 2012. Initially, the 2015 sealing status (CODE12) was copied to the 2012 sealing status (CODE12), 2009 sealing status (CODE09) and 2006 sealing status (CODE06) for all SSUs. If a change had occurred the appropriate attributes (CODE12 & CODE09 & CODE06) were updated as necessary. Again, if necessary, the UNCERTAIN and COMMENT attributes were used to record SSUs where the coding of sealing was unclear or certain issues occurred.

The assessment was made for the actual location where each SSU point feature lay in the guiding and reference data and visible in the imagery. For instance, roads under tree canopies are unsealed and structures over lawns are sealed.

#### 2.4.4. Estimation and analyses procedures

##### 2.4.4.1. Analysis of density values

As described above, density values from the reference data are not directly assessed, but generated from sampled data (SSUs). Therefore, these suffer from sampling error which needs to be considered in the analysis. This makes the use of correlation coefficient difficult to set a suitable threshold above which the correlation is deemed acceptable. The approach described below would be applicable to both status and change density layers.

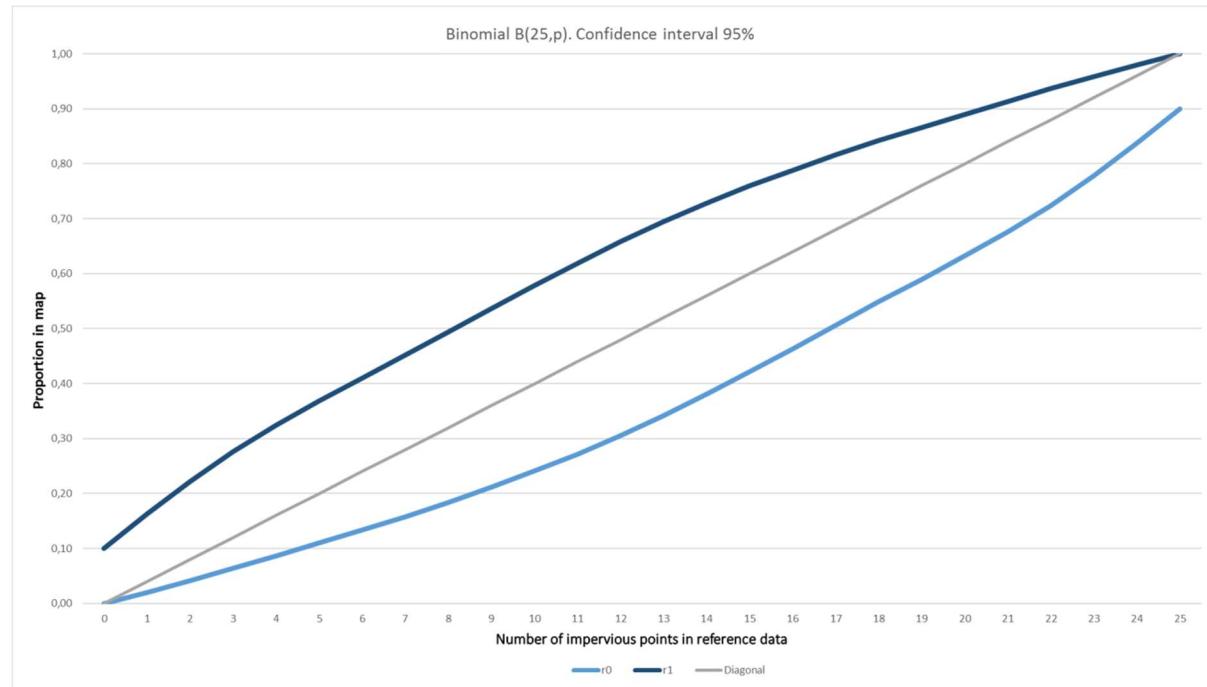
If we had a complete information on the cell for our reference data, a reasonable measure of the commission  $\varphi$  and omission  $\psi$  errors would be:

$$\varphi = \frac{\sum_i pos(m_i - r_i)}{\sum_i m_i} \quad \psi = \frac{\sum_i pos(r_i - m_i)}{\sum_i r_i} \quad (4)$$

where  $pos(x)$  is the positive part, i.e.  $pos(x) = x$  if  $x > 0$  and  $pos(x) = 0$  if  $x \leq 0$ .

If the map reports a proportion  $m_i$  and the reference data give a proportion  $r_i$ ,

For each sampling unit of 100 m we have a quantitative value in the map (estimated % in the satellite image classification) and a reference value that is an estimation obtained from a sample of 25 points. The number of impervious points that we are using as reference value has a probability distribution due to the within-cell sampling. If the within-sampling is random, the number of points follows a binomial  $B(25, p)$ . In our case the sampling scheme is systematic, but we use anyhow the binomial as an approximation.



**Figure 2-10. Representation of the behaviour of the 95% confidence interval for a 5x5 SSU grid over the whole range of imperviousness degree values**

Therefore, we cannot say that there is any significant disagreement if  $m_i$  lays within  $(r_{0i}, r_{1i})$  a confidence interval corresponding to  $B(25, r_i)$ . Figure 2-10 represents the behaviour of the 95% confidence interval for  $B(25, r_i)$ . Notice that only for proportions close to 0.5 we can apply the usual Gaussian approximation that leads to an interval approximately  $(r_i \pm 2s_i)$ , while for proportions close to 0 or to 1 the intervals are strongly asymmetric.

A possible adaptation of the formulas (4) above for the commission  $\varphi$  and omission errors  $\psi$  would be:

$$\varphi = \frac{\sum_i pos(m_i - r_{1i})}{\sum_i m_i} \quad \psi = \frac{\sum_i pos(r_{0i} - m_i)}{\sum_i r_i} \quad (5)$$

#### 2.4.4.2. Thematic accuracy

Thematic accuracy should be presented in the form of an error matrix. Unequal sampling intensity resulting from the stratified systematic sampling approach should be accounted for by applying a weight factor ( $p$ ) to each sample unit based on the ration between the number of samples and the size of the stratum considered:

$$\hat{p}_{ij} = \left(\frac{1}{N}\right) \sum_{x \in (i,j)} \frac{1}{\pi_{uh}^*}$$

Where  $i$  and  $j$  are the columns and rows in the matrix,  $N$  is the total number of possible units (population) and  $\pi$  is the sampling intensity for a given stratum.

Overall accuracy and User and producer accuracy should be computed for all thematic classes and 95% confidence intervals should be calculated for each accuracy.

The standard error of the error rate can be calculated as follows:  $\sigma_h = \sqrt{\frac{p_h(1-p_h)}{n_h}}$  where  $n_h$  is the sample size for stratum  $h$  and  $p_h$  is the expected error rate. The standard error is calculated for each stratum and an overall standard error is calculated based on the following formula:

$$\sigma = \sqrt{\sum w_h^2 \cdot \sigma_h^2}$$

In which  $w_h$  is the proportion of the total area covered by each stratum. The 95% confidence interval is +/- 1.96  $\sigma$ .

## 2.5. Temporal Quality

Temporal quality is evaluated by providing an indication of the closeness of the acquired image data to the reference year, e.g. the percentage area covered outside the accepted reference period as defined in the tender/product specification i.e. 2015 +/- 1-2 year(s).

## 2.6. Usability

Usability relates to the appropriateness of the metadata description and accompanying documentation to describe the processes and workflows involved in the production of the data. Although it is difficult to describe usability in quantitative terms, it provides a clear evaluation based on objective criteria of any limitation in the intended use of the data.

Assess the appropriateness of the metadata description and accompanying documentation. The accompanying documentation should be provided as a pdf and named as follows: CRS\_Information\_Sheet\_<country 2-letter ISO code>.e.g. CRS\_Information\_Sheet\_BG.pdf. These will be static and therefore will not have version numbers.

## 2.7. INSPIRE compliant metadata

Presence of INSPIRE compliant metadata should be verified.

### 3. Validation check list

#### 3.1. IMD2006

PRODUCT: IMD2006							
VALIDATION LEVEL: Pan-European							
SERVICE PROVIDER: SPECTO NATURA		SERVICE USER:		ISSUE/REVISION: 1.0			
VALIDATION DATE: 23/11/2018		REVIEW DATE:					
CONDUCTED BY: GEOFF SMITH		REVIEWED BY:		APPROVED BY:			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
1	COMPLETENESS						
1.1	Commission	Rate of excess items	OK	<ul style="list-style-type: none"> <li>Areas of marine water are mapped as unsealed (0)</li> <li>Inconsistent application of coastal maps.</li> </ul>			
1.2	Omission	Rate of missing items	OK				
2	LOGICAL CONSISTENCY						
2.1	Format consistency	File format	OK	<ul style="list-style-type: none"> <li>Additional supplementary files.</li> </ul>			
2.2		File name	NOK	<ul style="list-style-type: none"> <li>Version field does not match the specifications.</li> <li>“_d02_full” rather than “v1_1” etc.</li> </ul>			
2.3		Attributes names	n/a				
2.4		Attributes types	OK				

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data			
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK				
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.13		Multipart features	n/a	not applicable for raster data			
2.14		Neighbouring features	n/a	not applicable for raster data			
2.15		Self-intersections	n/a	not applicable for raster data			
2.16		Null geometry	n/a	not applicable for raster data			
2.17		Unclosed rings	n/a	not applicable for raster data			
2.18		Duplicate vertex	n/a	not applicable for raster data			
2.19		Pseudo nodes	n/a	not applicable for raster data			
2.20		Non matching nodes	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2006						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	<b>COMMENTS BY AUDIT TEAM</b>		Draft Audit Conclusion
3	<b>POSITIONAL ACCURACY</b>					
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic		
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic		
4	<b>THEMATIC ACCURACY</b>					
4.1	Classification correctness	Overall accuracy	OK	See section 4 for final thematic accuracy values of the products		
4.2		Min. producer's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.3		Min. user's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.4		Kappa	n/a	Not specified		

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				
7.3		File name	OK				

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>			

### 3.2. IMD2009

PRODUCT: IMD2009							
VALIDATION LEVEL: Pan-European							
SERVICE PROVIDER: SPECTO NATURA			SERVICE USER:	ISSUE/REVISION: 1.0			
VALIDATION DATE: 23/11/2018			REVIEW DATE:				
CONDUCTED BY: GEOFF SMITH			REVIEWED BY:	APPROVED BY:			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM			DRAFT AUDIT CONCLUSION
1	COMPLETENESS						
1.1	Commission	Rate of excess items	OK	<ul style="list-style-type: none"> <li>Areas of marine water are mapped as unsealed (0)</li> <li>Inconsistent application of coastal maps.</li> </ul>			
1.2	Omission	Rate of missing items	OK				
2	LOGICAL CONSISTENCY						
2.1	Format consistency	File format	OK	<ul style="list-style-type: none"> <li>Additional supplementary files.</li> </ul>			
2.2		File name	NOK	<ul style="list-style-type: none"> <li>Version field does not match the specifications.</li> <li>“_d02_full” rather than “v1_1” etc.</li> </ul>			
2.3		Attributes names	n/a				
2.4		Attributes types	OK				
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2009							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK				
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			
2.13		Multipart features	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2009						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion
2.14		Neighbouring features	n/a	not applicable for raster data		
2.15		Self-intersections	n/a	not applicable for raster data		
2.16		Null geometry	n/a	not applicable for raster data		
2.17		Unclosed rings	n/a	not applicable for raster data		
2.18		Duplicate vertex	n/a	not applicable for raster data		
2.19		Pseudo nodes	n/a	not applicable for raster data		
2.20		Non matching nodes	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMD2009						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	<b>DATA QUALITY SUB-</b>	<b>DATA QUALITY MEASURE</b>	<b>DATA QUALITY RESULT</b>	<b>COMMENTS BY AUDIT TEAM</b>	<b>DRAFT AUDIT CONCLUSION</b>	<b>FINAL AUDIT CONCLUSION</b>
3	<b>POSITIONAL ACCURACY</b>					
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the input images		
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the input images		
4	<b>THEMATIC ACCURACY</b>					
4.1	Classification correctness	Overall accuracy	OK	See section 4 for final thematic accuracy values of the products		
4.2		Min. producer's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.3		Min. user's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.4		Kappa	n/a	Not specified		

<b>PRODUCT:</b> IMD2009							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				
7.3		File name	OK				

<b>PRODUCT:</b> IMD2009							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>			

### 3.3. IMD2012

PRODUCT: IMD2012							
VALIDATION LEVEL: Pan-European							
SERVICE PROVIDER: SPECTO NATURA			SERVICE USER:	ISSUE/REVISION: 1.0			
VALIDATION DATE: 23/11/2018			REVIEW DATE:				
CONDUCTED BY: GEOFF SMITH			REVIEWED BY:	APPROVED BY:			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM			DRAFT AUDIT CONCLUSION
1	COMPLETENESS						
1.1	Commission	Rate of excess items	OK	<ul style="list-style-type: none"> <li>Only very minor areas of marine water are mapped as unsealed (0)</li> </ul>			
1.2	Omission	Rate of missing items	OK				
2	LOGICAL CONSISTENCY						
2.1	Format consistency	File format	OK	<ul style="list-style-type: none"> <li>Additional supplementary files.</li> </ul>			
2.2		File name	NOK	<ul style="list-style-type: none"> <li>Version field does not match the specifications.</li> <li>“_d02_full” rather than “v1_1” etc.</li> </ul>			
2.3		Attributes names	n/a				
2.4		Attributes types	OK				
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2012							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK				
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			
2.13		Multipart features	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2012						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion
2.14		Neighbouring features	n/a	not applicable for raster data		
2.15		Self-intersections	n/a	not applicable for raster data		
2.16		Null geometry	n/a	not applicable for raster data		
2.17		Unclosed rings	n/a	not applicable for raster data		
2.18		Duplicate vertex	n/a	not applicable for raster data		
2.19		Pseudo nodes	n/a	not applicable for raster data		
2.20		Non matching nodes	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMD2012						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	<b>COMMENTS BY AUDIT TEAM</b>		Draft Audit Conclusion
3	<b>POSITIONAL ACCURACY</b>					
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the input images		
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the input images		
4	<b>THEMATIC ACCURACY</b>					
4.1	Classification correctness	Overall accuracy	OK	See section 4 for final thematic accuracy values of the products		
4.2		Min. producer's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.3		Min. user's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.4		Kappa	n/a	Not specified		

<b>PRODUCT:</b> IMD2012							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				
7.3		File name	OK				

<b>PRODUCT:</b> IMD2012							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		<b>DRAFT AUDIT CONCLUSION</b>	<b>FINAL AUDIT CONCLUSION</b>
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>			

### 3.4. IMD2015

PRODUCT: IMD2015						
VALIDATION LEVEL: Pan-European						
SERVICE PROVIDER: SPECTO NATURA		SERVICE USER:		ISSUE/REVISION: 1.0		
VALIDATION DATE: 23/11/2018		REVIEW DATE:				
CONDUCTED BY: GEOFF SMITH		REVIEWED BY:		APPROVED BY:		
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM	DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
1	<b>COMPLETENESS</b>					
1.1	Commission	Rate of excess items	OK			
1.2	Omission	Rate of missing items	OK			
2	<b>LOGICAL CONSISTENCY</b>					
2.1	Format consistency	File format	OK	<ul style="list-style-type: none"> <li>Additional supplementary files.</li> <li>Two files less than the 2006, 2009 &amp; 2012 deliveries</li> </ul>		
2.2		File name	NOK	<ul style="list-style-type: none"> <li>Version field does not match the specifications.</li> <li>“_d02_full” rather than “v1_1” etc.</li> </ul>		
2.3		Attributes names	n/a			
2.4		Attributes types	OK			
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMD2015							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK				
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			
2.13		Multipart features	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2015						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion
2.14		Neighbouring features	n/a	not applicable for raster data		
2.15		Self-intersections	n/a	not applicable for raster data		
2.16		Null geometry	n/a	not applicable for raster data		
2.17		Unclosed rings	n/a	not applicable for raster data		
2.18		Duplicate vertex	n/a	not applicable for raster data		
2.19		Pseudo nodes	n/a	not applicable for raster data		
2.20		Non matching nodes	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMD2015						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	<b>DATA QUALITY SUB-</b>	<b>DATA QUALITY MEASURE</b>	<b>DATA QUALITY RESULT</b>	<b>COMMENTS BY AUDIT TEAM</b>	<b>DRAFT AUDIT CONCLUSION</b>	<b>FINAL AUDIT CONCLUSION</b>
3	<b>POSITIONAL ACCURACY</b>					
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the input images		
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the input images		
4	<b>THEMATIC ACCURACY</b>					
4.1	Classification correctness	Overall accuracy	OK	See section 4 for final thematic accuracy values of the products		
4.2		Min. producer's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.3		Min. user's accuracy	OK NOK	See section 4 for final thematic accuracy values of the products		
4.4		Kappa	n/a	Not specified		

<b>PRODUCT:</b> IMD2015							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				
7.3		File name	OK				

<b>PRODUCT:</b> IMD2015							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>			

### 3.5. IMC0609

PRODUCT: IMC0609						
VALIDATION LEVEL: Pan-European						
SERVICE PROVIDER: SPECTO NATURA		SERVICE USER:		ISSUE/REVISION: 1.0		
VALIDATION DATE: 23/11/2018		REVIEW DATE:				
CONDUCTED BY: GEOFF SMITH		REVIEWED BY:		APPROVED BY:		
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM	DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
1	<b>COMPLETENESS</b>					
1.1	Commission	Rate of excess items	OK			
1.2	Omission	Rate of missing items	OK			
2	<b>LOGICAL CONSISTENCY</b>					
2.1	Format consistency	File format	OK	• Additional supplementary files.		
2.2		File name	NOK	• Version field does not match the specifications. • “_d02_full” rather than “v1_1” etc.		
2.3		Attributes names	n/a			
2.4		Attributes types	OK			
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMC0609							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK	<ul style="list-style-type: none"> <li>• No colour coding</li> <li>• Loads as "Continuous" or "Greyscale"</li> </ul>			
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			
2.13		Multipart features	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMC0609						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion
2.14		Neighbouring features	n/a	not applicable for raster data		
2.15		Self-intersections	n/a	not applicable for raster data		
2.16		Null geometry	n/a	not applicable for raster data		
2.17		Unclosed rings	n/a	not applicable for raster data		
2.18		Duplicate vertex	n/a	not applicable for raster data		
2.19		Pseudo nodes	n/a	not applicable for raster data		
2.20		Non matching nodes	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMC0609							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
3	<b>POSITIONAL ACCURACY</b>						
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic			
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic			
4	<b>THEMATIC ACCURACY</b>						
4.1	Classification correctness	Overall accuracy	OK	See section 5 for final thematic accuracy values of the products			
4.2		Min. producer's accuracy	OK NOK	See section 5 for final thematic accuracy values of the products			
4.3		Min. user's accuracy	OK NOK	See section 5 for final thematic accuracy values of the products			
4.4		Kappa	n/a	Not specified			

<b>PRODUCT:</b> IMC0609							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				
7.3		File name	OK				

<b>PRODUCT:</b> IMC0609							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>			

### 3.6. IMC0912

PRODUCT: IMC0912						
VALIDATION LEVEL: Pan-European						
SERVICE PROVIDER: SPECTO NATURA		SERVICE USER:		ISSUE/REVISION: 1.0		
VALIDATION DATE: 23/11/2018		REVIEW DATE:				
CONDUCTED BY: GEOFF SMITH		REVIEWED BY:		APPROVED BY:		
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM	DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
1	<b>COMPLETENESS</b>					
1.1	Commission	Rate of excess items	OK			
1.2	Omission	Rate of missing items	OK			
2	<b>LOGICAL CONSISTENCY</b>					
2.1	Format consistency	File format	OK	• Additional supplementary files.		
2.2		File name	NOK	• Version field does not match the specifications. • “_d02_full” rather than “v1_1” etc.		
2.3		Attributes names	n/a			
2.4		Attributes types	OK			
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMC0912							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK	<ul style="list-style-type: none"> <li>• No colour coding</li> <li>• Loads as "Continuous" or "Greyscale"</li> </ul>			
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			
2.13		Multipart features	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMC0912							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.14		Neighbouring features	n/a	not applicable for raster data			
2.15		Self-intersections	n/a	not applicable for raster data			
2.16		Null geometry	n/a	not applicable for raster data			
2.17		Unclosed rings	n/a	not applicable for raster data			
2.18		Duplicate vertex	n/a	not applicable for raster data			
2.19		Pseudo nodes	n/a	not applicable for raster data			
2.20		Non matching nodes	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMC0912							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
3	<b>POSITIONAL ACCURACY</b>						
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic			
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic			
4	<b>THEMATIC ACCURACY</b>						
4.1	Classification correctness	Overall accuracy	OK	See section 5 for final thematic accuracy values of the products			
4.2		Min. producer's accuracy	OK NOK	See section 5 for final thematic accuracy values of the products			
4.3		Min. user's accuracy	OK NOK	See section 5 for final thematic accuracy values of the products			
4.4		Kappa	n/a	Not specified			

<b>PRODUCT:</b> IMC0912							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> <li>• Difficult to display in QGIS.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				

<b>PRODUCT:</b> IMC0912						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM	DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
7.3		File name	OK			
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>		

### 3.7. IMC1215

PRODUCT: IMD2006						
VALIDATION LEVEL: Pan-European						
SERVICE PROVIDER: SPECTO NATURA		SERVICE USER:		ISSUE/REVISION: 1.0		
VALIDATION DATE: 23/11/2018		REVIEW DATE:				
CONDUCTED BY: GEOFF SMITH		REVIEWED BY:		APPROVED BY:		
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM	DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
1	<b>COMPLETENESS</b>					
1.1	Commission	Rate of excess items	OK			
1.2	Omission	Rate of missing items	OK			
2	<b>LOGICAL CONSISTENCY</b>					
2.1	Format consistency	File format	OK	• Additional supplementary files.		
2.2		File name	NOK	• Version field does not match the specifications. • “_d02_full” rather than “v1_1” etc.		
2.3		Attributes names	n/a			
2.4		Attributes types	OK			
2.5	Conceptual consistency	Feature type	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
2.6		MMU	OK				
2.7		Coordinate reference system	OK				
2.8		Unique identifier	n/a	not applicable for raster data			
2.9		Nomenclature	OK	<ul style="list-style-type: none"> <li>• No colour coding</li> <li>• Loads as "Continuous" or "Greyscale"</li> </ul>			
2.10	Domaine consistency	Value domain non-conformance	OK				
2.11	Topological consistency	Overlaps	n/a	not applicable for raster data			
2.12		Gaps	n/a	not applicable for raster data			
2.13		Multipart features	n/a	not applicable for raster data			

<b>PRODUCT:</b> IMD2006						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion
2.14		Neighbouring features	n/a	not applicable for raster data		
2.15		Self-intersections	n/a	not applicable for raster data		
2.16		Null geometry	n/a	not applicable for raster data		
2.17		Unclosed rings	n/a	not applicable for raster data		
2.18		Duplicate vertex	n/a	not applicable for raster data		
2.19		Pseudo nodes	n/a	not applicable for raster data		
2.20		Non matching nodes	n/a	not applicable for raster data		

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	Data Quality Sub-	Data Quality Measure	Data Quality Result	Comments by Audit Team		Draft Audit Conclusion	Final Audit Conclusion
3	<b>POSITIONAL ACCURACY</b>						
3.1	Absolute or external accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic			
3.2	Relative or internal accuracy	RMSEP	n/a	This is dependent on the assessment of the CORE001 mosaic			
4	<b>THEMATIC ACCURACY</b>						
4.1	Classification correctness	Overall accuracy	OK	See section 5 for final thematic accuracy values of the products			
4.2		Min. producer's accuracy	OK NOK	See section 5 for final thematic accuracy values of the products			
4.3		Min. user's accuracy	OK NOK	See section 5 for final thematic accuracy values of the products			
4.4		Kappa	n/a	Not specified			

<b>PRODUCT:</b> IMD2006							
<b>VALIDATION LEVEL:</b> Pan-European							
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0			
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>				
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>			
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	<b>COMMENTS BY AUDIT TEAM</b>		DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
5	<b>TEMPORAL QUALITY</b>						
5.1	Temporal quality	Closeness of the acquired image data to the reference year		No information available			
6	<b>USABILITY</b>						
6.1	Usability	Usability description	NOK	<ul style="list-style-type: none"> <li>• No CRS Information Sheets in PDF format.</li> <li>• Different supplementary files, even when using the same image format.</li> <li>• Behaviour is different in different image processing systems, likely to be related to associated files.</li> <li>• Difficult to display in QGIS.</li> </ul>			
7	<b>METADATA</b>						
7.1	INSPIRE compliant metadata	Presence	OK				
7.2		File format	OK				

<b>PRODUCT:</b> IMD2006						
<b>VALIDATION LEVEL:</b> Pan-European						
<b>SERVICE PROVIDER:</b> SPECTO NATURA			<b>SERVICE USER:</b>	<b>ISSUE/REVISION:</b> 1.0		
<b>VALIDATION DATE:</b> 23/11/2018			<b>REVIEW DATE:</b>			
<b>CONDUCTED BY:</b> GEOFF SMITH			<b>REVIEWED BY:</b>	<b>APPROVED BY:</b>		
No.	DATA QUALITY SUB-	DATA QUALITY MEASURE	DATA QUALITY RESULT	COMMENTS BY AUDIT TEAM	DRAFT AUDIT CONCLUSION	FINAL AUDIT CONCLUSION
7.3		File name	OK			
7.4		INSPIRE compliance	NOK	<ul style="list-style-type: none"> <li>Missing or wrong Originating Controlled Vocabulary URI - URI needs to be '<a href="http://www.eionet.europa.eu/gemet/inspire_themes">http://www.eionet.europa.eu/gemet/inspire_themes</a>'.</li> <li>Missing or wrong Keyword URI - URI needs to be '<a href="http://inspire.ec.europa.eu/theme/lu">http://inspire.ec.europa.eu/theme/lu</a>'</li> </ul>		

## 4. Thematic accuracy IMD

The thematic accuracy is assessed using a number of approaches and within a number of regionalisations to better understand the thematic characteristics across biogeographic regions and countries.

The assessment was based on an original sample set of 18005 reference points. Due to missing values in some of the mapped products the maximum number of reference points with valid mapped and reference values was 17912.

### 4.1. IMD scatterplots & regression analysis

A scatterplot is a way of displaying data against Cartesian coordinates to show and compare values for two variables within a dataset. The data is displayed as a series of points, where the x and y locations relate two variables assigned to a particular recording instance, in this case a PSU. The three available measurements for each PSU are the original reference data (CODE), the reference data after plausibility analysis (QC) and the mapped value from the product (MAP). For this validation exercise the position / value on the horizontal axis represented the reference (CODE or QC) information and the position / value on the vertical axis represents product (MAP) information. In this way the relation of the reference and product information for a point can be compared to a 1:1 line which runs diagonally across the scatter plot. The closeness of a point to the point to the 1:1 line is an indication of the similarity between the reference and mapped results. The points that lie exactly on the x and y axes are related to omission and commission rather than the calibration of the IMD values themselves.

The challenge of accurately recording imperviousness in 20 m EO data and then aggregating this to a 1 ha grid is obvious from the distribution of points displayed on Figure 4-1. The plots for both blind interpretation and plausibility analysis show considerable scatter of up to 20 % each side of the best fit line. There are also considerable numbers of point on the x and y axes showing commission, where sealing is mapped that is not present in reality, and omission, where sealed areas are missed. It can also be seen that the distribution is not centred on the 1:1 line but falls below the line indicating that the mapped products are underestimating the actual imperviousness as reported by the reference data. In the case of the plausibility analysis the spread of points around the best fit line is slightly reduced as would be expected. These conclusions are repeated consistently across the different dates and between the blind interpretation and the plausibility analysis.

The scatterplots and the resulting best fit lines are controlled by the actual geography of the regions being considered so can differ significantly from the results presented in Figure 4-1 when considering Europe as a whole. In Figure 4-2 the results for the Arctic BRME zone show that there are limited number of sealed areas, the areas present tend to have low imperviousness values and the relationship between the reference and mapped data is controlled by a single point. In this case has resulted in imperviousness being significantly underestimated relative to the reference data. There are also a number of omissions and commissions which is highly likely for a region where vegetation is limited and there may be extensive areas of bare rock.

The Atlantic BRME zone (Figure 4-3) is more representative of Europe as a whole and contains significant sealed areas of varying imperviousness. The distribution of reference points appears to consist of two groups. Those near the best fit line and outliers with both greater over and under estimation of imperviousness. There is also a significant group of points which are marked as completely sealed (100 % imperviousness) in the reference data but range from around 70 to 100 % in the mapped data, which may indicate that certain sealed surfaces are more difficult to detect or calibrated for in the EO data. In this example it can be seen that the plausibility analysis removes some of the commission and omission errors.

What is not obvious on these scatterplots is the impact of the large numbers of values which tend to lie on the x and y axis and the origin of the plots that distort the visual appearance of the scatterplots and the regression results.

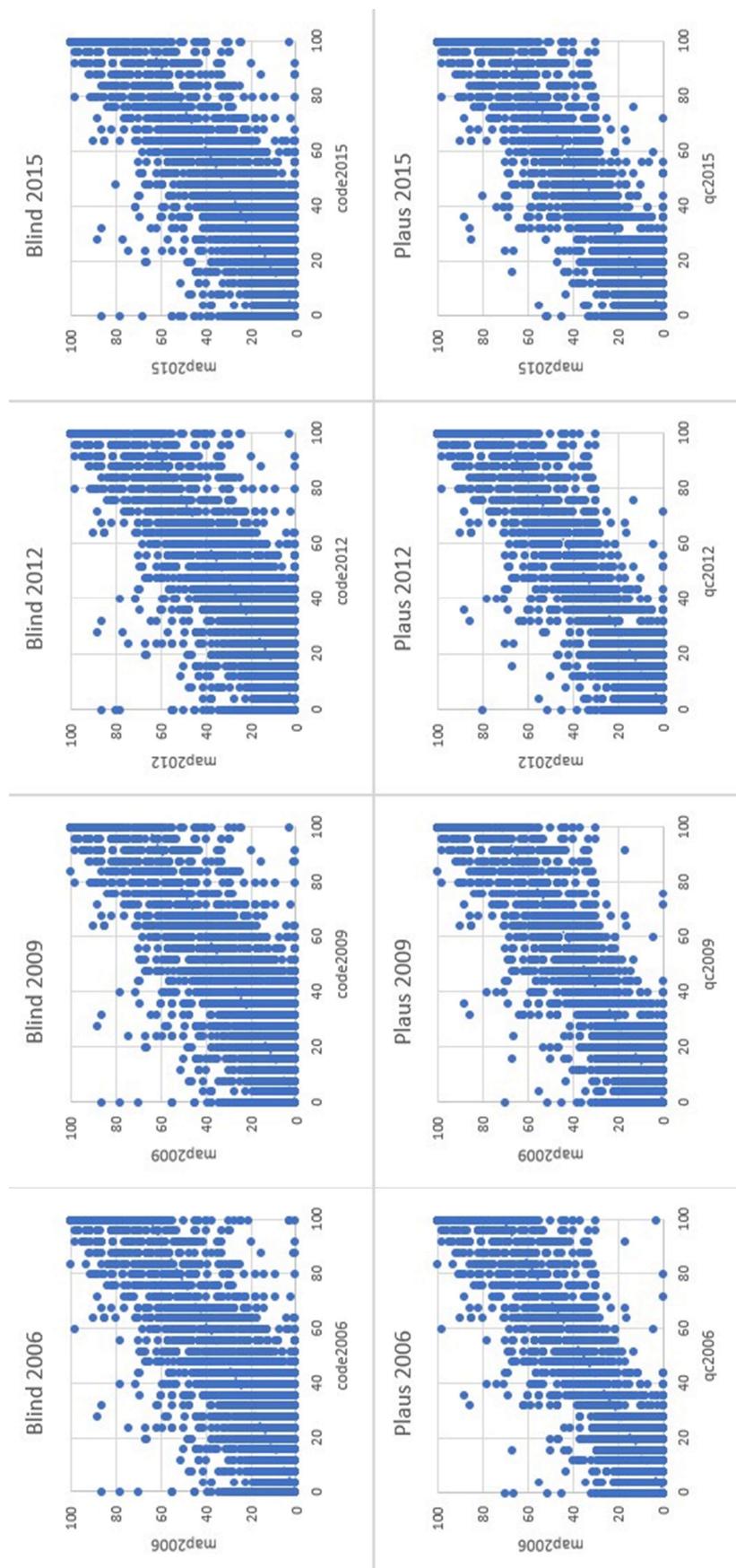


Figure 4-1: Scatterplots for all four years for ALL the reference data for IMD for both the blind interpretation (CODE) and plausibility analysis (QC).

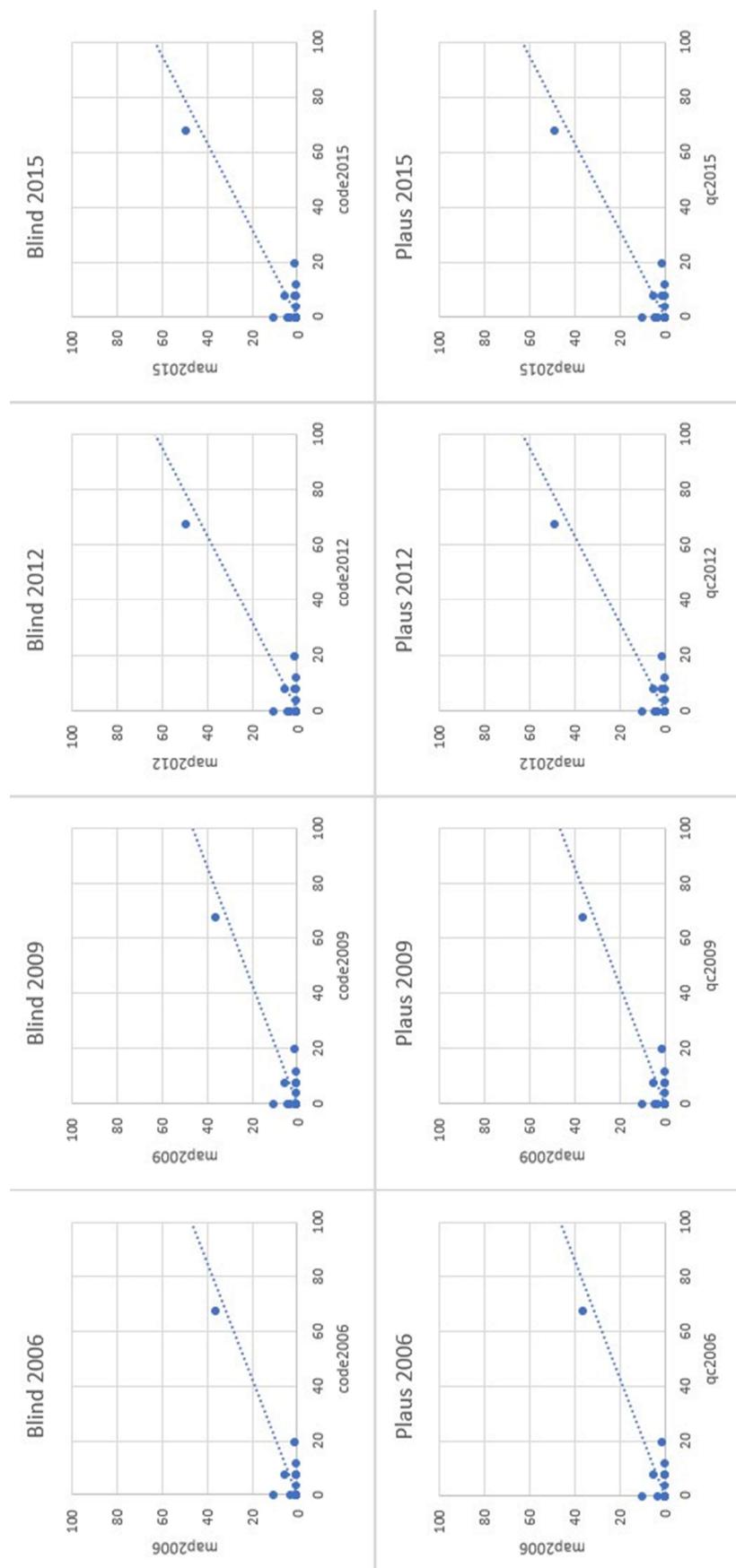


Figure 4-2: Scatterplots for all four years for Arctic (ARC) BRME zone for IMD for both the blind interpretation (CODE) and plausibility analysis (QC).

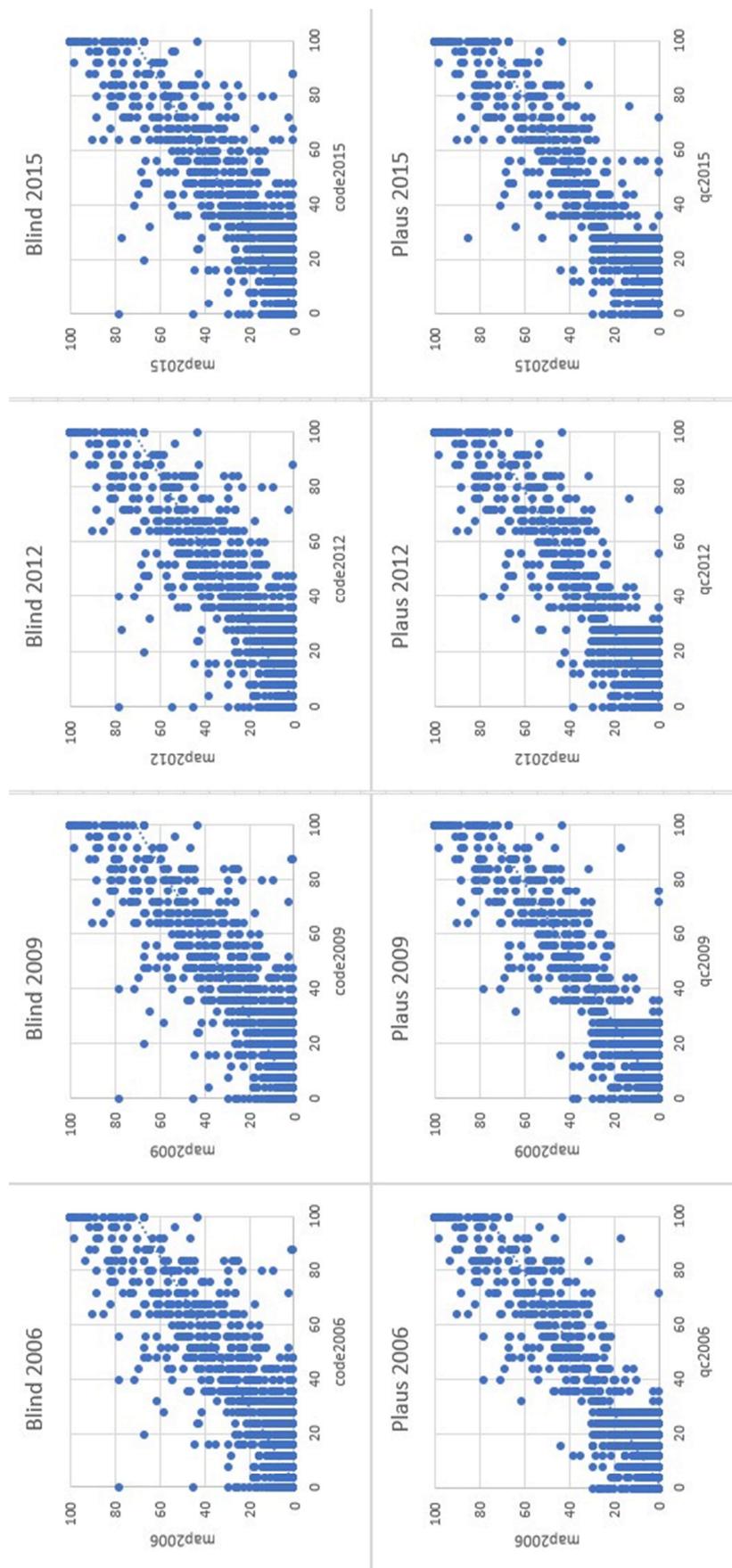


Figure 4-3: Scatterplots for all four years for Atlantic (ATL) BRME zone for IMD for both the blind interpretation (CODE) and plausibility analysis (QC).

To quantitatively summarise the results displayed in the scatterplots above a linear regression analysis is performed to estimate the relationships between the reference and mapped product information. The analysis produces a coefficient of determination ( $R^2$ ) which gives information about the goodness of fit of the estimated regression model. Coefficients of determination closer to 1 represent a better fit. In this case as the reference and map information are meant to represent the same information then it is useful to also consider the slope and intercept of the estimated regression model. The slope should therefore approach 1 and the intercept should be close to 0 for the required relationships. Deviations from the expected values give an indication of the correspondence of the reference and mapped imperviousness data.

The results of the regression analysis of the map imperviousness densities to the reference data are given in Table 4-1 for the blind interpretation and Table 4-2 for the plausibility analysis. There are some missing items in the table due to data for the French DOMs not being available at the time of analysis.

Since the reprocessing of the 2006, 2009 and 2012 data it is obvious that the results are now more consistent across the epochs. Compared to the results produced when validating the 2012 IMD data the range of  $R^2$  and slope values have reduced, particularly at the lower end suggesting there were spatially dependent calibrations issues in the previous versions. The slope values have all become less than 1.0 compared to a range of 0.25 to 1.17 when validating the 2012 IMD. This suggests that there is now a consistent under estimation of the imperviousness across the extent of the product and across the epochs.

Overall, there is a slight overall increasing trend in the  $R^2$  values across time within the majority of regionalisations, however this is unlikely to be significant in most cases. There is still considerable variation between the regions with  $R^2$  ranging from 0.44, a very weak relationship, to 0.90, suggesting a strong correspondence between the reference and mapped data. As expected the lowest values are for the regions where there are few points or limited amounts of sealed surfaces such as the Macaronesian BRME region. The highest values of  $R^2$  were consistently for Iceland where the reference points are dominated by low or zero imperviousness values and there is a single point with an imperviousness value of 68 % meaning the majority of points fall close to the regression line. These values are not only affected by the changing character and make-up of the landscape, but also the numbers of samples used in each region.

As the regression analysis used all the reference points this time the dominance of unsealed areas resulted in all the intercept values being close to zero. The slopes values range from 0.40 to 0.79 confirming the underestimation identified in the scatterplots. The slope for the whole dataset of around 0.67 suggests a general underestimation of imperviousness in the IMD layer of around 30 % compared to the reference data.

As expected the plausibility analysis results give high  $R^2$  values as more of the outliers have been adjusted to account for uncertainties in the validation approach. The  $R^2$  for the pan-European (ALL) data rose from around 0.78 to 0.84 and the  $R^2$  values at the lower end for the regions rose from around 0.40 to 0.48. The slope values for almost all regions and dates increased towards 1.0 suggesting an improvement to the calibration. The pan-European (ALL) slopes increased by 0.06 and the regions had a maximum increase in of 0.15.

**Table 4-1: A summary of regression line parameters for the scatterplots derived from the blind interpretation as reference data.**

	n	2006			2009			2012			2015		
		R <sup>2</sup>	Slp	Int									
European All	17912	0.77	0.66	-0.63	0.78	0.66	-0.64	0.78	0.67	-0.62	0.78	0.67	-0.63
ALP	1915	0.77	0.58	-0.30	0.77	0.59	-0.29	0.78	0.59	-0.31	0.78	0.59	-0.31
ANA	1142	0.62	0.47	0.01	0.61	0.47	0.03	0.61	0.48	0.04	0.62	0.48	0.05
ARC	244	0.82	0.47	-0.02	0.81	0.47	0.00	0.84	0.63	-0.03	0.84	0.63	-0.03
ATL	2968	0.80	0.72	-1.28	0.80	0.72	-1.24	0.81	0.73	-1.22	0.81	0.73	-1.25
BLS	331	0.48	0.38	0.01	0.48	0.38	0.01	0.48	0.38	0.00	0.50	0.43	0.00
BOR	2569	0.67	0.45	-0.29	0.67	0.45	-0.31	0.68	0.45	-0.30	0.68	0.46	-0.31
CON	4629	0.78	0.69	-0.71	0.79	0.70	-0.73	0.78	0.70	-0.68	0.78	0.70	-0.71
MAC	37	0.44	0.48	0.27	0.44	0.48	0.27	0.44	0.48	0.27	0.43	0.48	0.33
MED	3521	0.77	0.65	-0.59	0.79	0.66	-0.61	0.80	0.67	-0.62	0.79	0.67	-0.62
PAN	448	0.83	0.50	-0.31	0.83	0.51	-0.32	0.81	0.51	-0.20	0.83	0.52	-0.29
STE	108	0.85	0.53	-0.47	0.85	0.53	-0.47	0.85	0.53	-0.47	0.85	0.53	-0.47
AL+ME+MK+RS+XK	472	0.77	0.50	-0.29	0.77	0.50	-0.29	0.74	0.50	-0.21	0.76	0.51	-0.29
AT + CH + LI	411	0.81	0.71	-0.75	0.81	0.71	-0.74	0.82	0.72	-0.78	0.82	0.72	-0.78
BA + HR + SI	419	0.75	0.65	-0.62	0.75	0.65	-0.62	0.77	0.65	-0.65	0.76	0.65	-0.64
BE + LU+ NL + DK	473	0.80	0.77	-0.57	0.82	0.79	-0.69	0.81	0.79	-0.64	0.82	0.79	-0.82
BG	322	0.75	0.66	0.13	0.81	0.66	0.66	0.81	0.66	0.19	0.81	0.66	0.19
CZ + SK	403	0.84	0.79	0.07	0.83	0.79	0.15	0.83	0.79	0.16	0.84	0.79	0.11
DE	1300	0.82	0.75	-1.13	0.83	0.75	-1.09	0.82	0.75	-1.02	0.82	0.75	-1.11
EE + LT + LV	547	0.79	0.60	-0.41	0.78	0.60	-0.38	0.78	0.60	-0.36	0.78	0.63	-0.44
EL	418	0.80	0.65	-0.66	0.80	0.65	-0.69	0.80	0.64	-0.68	0.82	0.65	-0.75
ES	1469	0.74	0.60	-0.52	0.77	0.62	-0.54	0.77	0.62	-0.52	0.77	0.63	-0.54
FI	973	0.69	0.40	-0.17	0.70	0.40	-0.22	0.71	0.41	-0.22	0.71	0.41	-0.21
FR	1811	0.77	0.67	-1.36	0.77	0.68	-1.36	0.78	0.69	-1.38	0.78	0.69	-1.38
FR DOMs													
HU	294	0.81	0.52	-0.56	0.81	0.53	-0.57	0.82	0.53	-0.57	0.82	0.54	-0.60
IE + UK	1022	0.83	0.71	-0.66	0.82	0.71	-0.61	0.83	0.73	-0.56	0.82	0.71	-0.58
IS	234	0.87	0.50	0.00	0.86	0.50	0.02	0.90	0.68	-0.01	0.90	0.68	-0.01
IT	1046	0.76	0.64	-1.11	0.77	0.65	-1.16	0.79	0.66	-1.25	0.79	0.66	-1.25
NO	860	0.62	0.45	-0.22	0.62	0.45	-0.22	0.63	0.45	-0.22	0.63	0.45	-0.22
PL	1049	0.73	0.72	-0.77	0.73	0.72	-0.79	0.72	0.73	-0.72	0.72	0.73	-0.65
PT	315	0.80	0.75	-0.93	0.80	0.76	-0.94	0.80	0.76	-0.93	0.81	0.75	-1.00
RO	735	0.83	0.47	-0.35	0.83	0.47	-0.35	0.83	0.47	-0.36	0.81	0.49	-0.38
SE	1213	0.61	0.44	-0.40	0.61	0.44	-0.40	0.63	0.45	-0.40	0.63	0.45	-0.39
TR	2126	0.73	0.59	-0.27	0.73	0.59	-0.26	0.73	0.60	-0.25	0.70	0.60	-0.16

**Table 4-2: A summary of regression line parameters for the scatterplots derived from the plausibility analysis as reference data.**

	n	2006			2009			2012			2015		
		R <sup>2</sup>	Slp	Int									
European All	17912	0.83	0.73	-0.65	0.84	0.73	-0.66	0.84	0.73	-0.65	0.84	0.73	-0.68
ALP	1915	0.82	0.65	-0.31	0.82	0.65	-0.30	0.83	0.66	-0.32	0.83	0.66	-0.32
ANA	1142	0.71	0.56	-0.06	0.71	0.56	-0.05	0.71	0.58	-0.05	0.74	0.57	-0.06
ARC	244	0.82	0.47	-0.02	0.81	0.47	0.00	0.84	0.63	-0.03	0.84	0.63	-0.03
ATL	2968	0.86	0.78	-1.28	0.86	0.78	-1.22	0.86	0.79	-1.21	0.86	0.78	-1.29
BLS	331	0.48	0.50	-0.12	0.48	0.50	-0.12	0.47	0.50	-0.13	0.53	0.58	-0.19
BOR	2569	0.73	0.55	-0.40	0.73	0.55	-0.41	0.73	0.55	-0.40	0.73	0.56	-0.42
CON	4629	0.84	0.76	-0.73	0.84	0.76	-0.74	0.84	0.77	-0.70	0.85	0.77	-0.76
MAC	37	0.48	0.53	0.04	0.48	0.53	0.04	0.48	0.53	0.04	0.48	0.53	0.10
MED	3521	0.84	0.71	-0.64	0.85	0.72	-0.65	0.85	0.72	-0.67	0.85	0.72	-0.67
PAN	448	0.84	0.58	0.00	0.84	0.59	0.00	0.84	0.59	0.03	0.84	0.59	0.02
STE	108	0.76	0.60	-0.02	0.76	0.60	-0.02	0.76	0.60	-0.02	0.82	0.61	-0.24
AL+ME+MK+RS+XK	472	0.82	0.59	-0.25	0.82	0.59	0.26	0.82	0.60	-0.26	0.82	0.60	-0.28
AT + CH + LI	411	0.86	0.76	-0.76	0.87	0.77	-0.75	0.87	0.77	-0.78	0.87	0.77	-0.78
BA + HR + SI	419	0.79	0.70	-0.64	0.79	0.70	-0.64	0.79	0.70	0.68	0.80	0.70	-0.66
BE + LU+ NL + DK	473	0.86	0.81	-0.77	0.87	0.81	-0.79	0.89	0.83	-0.98	0.89	0.83	-1.09
BG	322	0.86	0.77	-0.06	0.90	0.74	-0.02	0.89	0.74	0.01	0.89	0.74	0.01
CZ + SK	403	0.87	0.83	0.14	0.86	0.83	0.20	0.86	0.83	0.22	0.86	0.83	0.20
DE	1300	0.86	0.80	-0.91	0.86	0.80	-0.86	0.85	0.80	-0.83	0.87	0.81	-1.01
EE + LT + LV	547	0.78	0.64	-0.34	0.77	0.64	-0.31	0.78	0.64	-0.29	0.78	0.67	-0.38
EL	418	0.79	0.65	-0.60	0.79	0.66	-0.63	0.80	0.65	-0.58	0.80	0.65	-0.58
ES	1469	0.79	0.65	-0.55	0.82	0.67	-0.57	0.82	0.67	-0.58	0.82	0.67	-0.59
FI	973	0.71	0.48	-0.24	0.72	0.48	-0.28	0.72	0.48	-0.28	0.72	0.48	-0.27
FR	1811	0.83	0.75	-1.36	0.83	0.75	-1.37	0.83	0.76	-1.32	0.84	0.76	-1.38
FR DOMs													
HU	294	0.84	0.63	-0.28	0.84	0.63	-0.28	0.85	0.63	-0.27	0.84	0.64	-0.30
IE + UK	1022	0.88	0.76	-0.73	0.88	0.76	-0.67	0.87	0.77	-0.58	0.86	0.76	-0.64
IS	234	0.87	0.50	0.00	0.86	0.50	0.02	0.90	0.68	-0.01	0.90	0.68	-0.01
IT	1046	0.86	0.71	-1.30	0.87	0.72	-1.32	0.87	0.73	-1.39	0.87	0.73	-1.42
NO	860	0.72	0.55	-0.31	0.72	0.55	-0.31	0.72	0.55	-0.30	0.72	0.55	-0.30
PL	1049	0.80	0.80	-0.85	0.80	0.80	-0.87	0.80	0.81	0.84	0.80	0.81	-0.85
PT	315	0.85	0.80	-0.93	0.84	0.81	-0.88	0.85	0.81	-0.95	0.84	0.80	-0.93
RO	735	0.80	0.54	-0.09	0.80	0.54	-0.09	0.80	0.55	-0.10	0.82	0.57	-0.21
SE	1213	0.73	0.58	-0.58	0.73	0.58	-0.58	0.73	0.59	-0.56	0.73	0.59	-0.56
TR	2126	0.80	0.66	-0.29	0.80	0.67	-0.29	0.80	0.67	-0.28	0.80	0.67	-0.26

## 4.2. IMD review of reference data

As results in section 4.1 suggested there was a consistent and significant underestimation of imperviousness by the re-processed IMD layer the reference data were examined to assess its consistency against reference data used in the past.

As there was a change in the reference data PSU distribution between 2012 and 2015, a subset of PSU were identified which were common between the two reference data collections. At the 5080 common PSU points the previous and new reference values for imperviousness density were compared. Although the overall relationship between the two reference collections seemed strong with a regression slope close to 1.0, an analysis of the individual differences showed that over estimation by the new 2012 imperviousness density values dominants (Figure 4-4). This would suggest that, in part, the underestimation identified in the IMD layers was due to overestimation in the reference data.

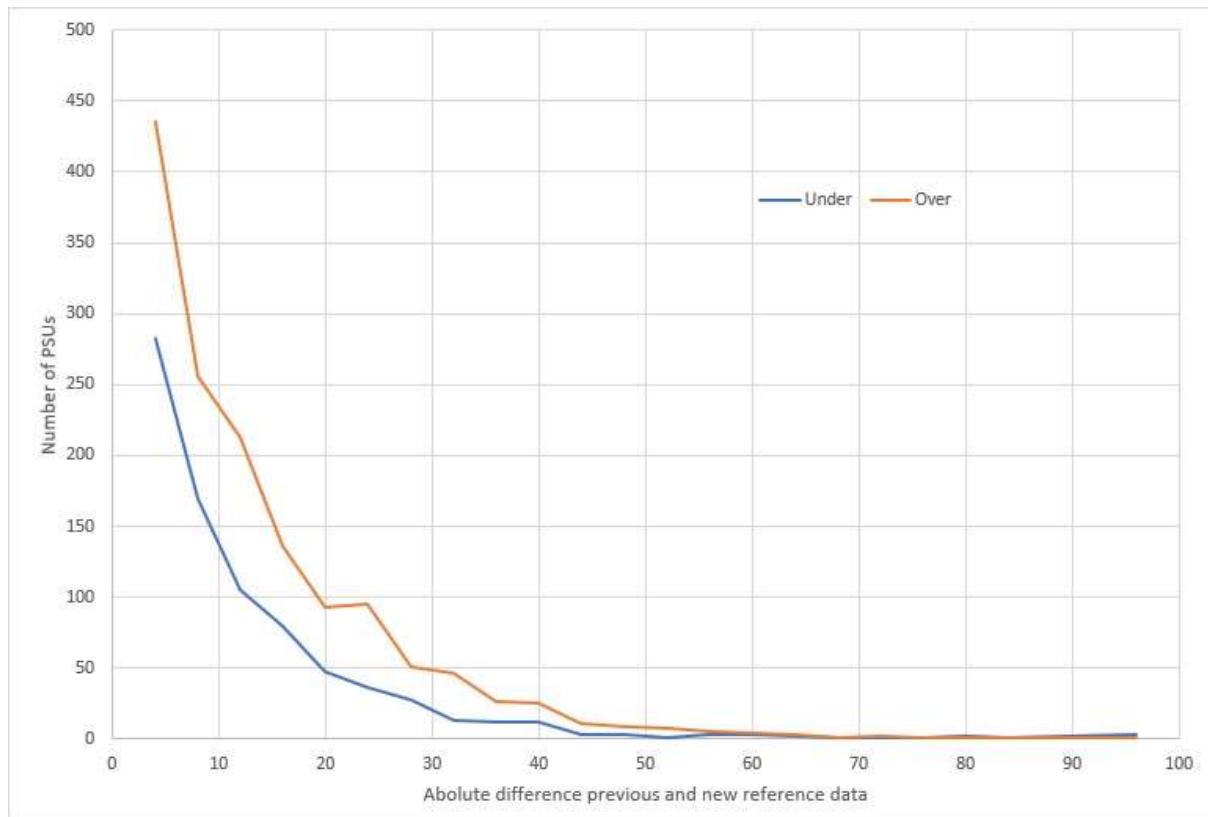


Figure 4-4. A plot showing the differences identified in the 2012 and 2015 reference data collections divided into under and over estimations.

### 4.3. IMD blind interpretation correspondence analysis

For each of the regionalisations, the correspondence analysis (user's and producer's accuracies) and the 95 % confidence intervals were calculated. The results for the blind interpretation are given in Table 4-3 which shows the correspondence analysis for the blind interpretation and mapped values of imperviousness converted to urban area using a 30% threshold. The overall accuracies, which were not part of the product specification, exceeded the target thematic accuracy 90% (not shown for clarity) but these were not representative as the urban area makes up a relatively small fraction of the European landscape even in the most densely built-up areas.

It is more appropriate therefore to consider the user's and producer's accuracies, where around half of the regionalisations achieved the required thematic accuracy of 90 % with a small number falling just short of the requirement, but within 5 %. The user's accuracy, or error of commission, tends to reach the requirement, whereas the producer's accuracy, errors of omission, tend to fall considerably short of the requirement. As with the regressions there is a level of consistency of the results across time due to the reprocessing of the 2006, 2009 and 2012 results. The correspondence results are more variable across the regionalisations due to the sizes of the regions and the distribution of urban areas across Europe. Also, the high thematic accuracies tend to be associated with the user's rather than producer's accuracy supporting the conclusion that the IMD layers are under over estimating imperviousness and therefore creating omission errors in the urban layer.

**Table 4-3: A summary of the correspondence results for the blind interpretation for the reprocessed 2006, 2009 and 2012 data and the 2015 results. Green cells exceed the 90 % minimum accuracy requirement, orange cells are within 5% and red cells fall more than 5% short.**

	2006				2009				2012				2015			
	User	CI95%	Prod	CI95%												
European All	92,28%	0,05%	54,25%	0,32%	91,86%	0,05%	54,66%	0,32%	91,53%	0,06%	55,38%	0,32%	91,78%	0,05%	55,10%	0,34%
ALP	96,00%	0,01%	52,17%	0,04%	94,12%	0,02%	52,17%	0,04%	94,23%	0,02%	52,13%	0,04%	94,23%	0,02%	52,13%	0,04%
ANA	72,00%	0,03%	43,90%	0,04%	69,23%	0,03%	43,90%	0,04%	67,86%	0,03%	44,19%	0,04%	67,86%	0,03%	43,18%	0,04%
ARC	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%
ATL	96,30%	0,07%	58,69%	0,22%	95,36%	0,07%	58,61%	0,22%	95,18%	0,07%	59,76%	0,22%	95,53%	0,07%	59,24%	0,26%
BLS	75,00%	0,04%	18,75%	0,04%	75,00%	0,04%	18,75%	0,04%	75,00%	0,04%	18,75%	0,04%	80,00%	0,04%	22,22%	0,04%
BOR	100,00%	0,00%	31,22%	0,49%	100,00%	0,00%	31,22%	0,49%	100,00%	0,00%	34,56%	0,49%	100,00%	0,00%	34,56%	0,49%
CON	91,19%	0,08%	56,95%	0,34%	91,07%	0,08%	57,39%	0,34%	90,27%	0,09%	57,82%	0,33%	90,32%	0,09%	57,28%	0,35%
MAC	50,00%	0,15%	25,00%	0,25%	50,00%	0,15%	25,00%	0,25%	50,00%	0,15%	25,00%	0,25%	50,00%	0,15%	25,00%	0,25%
MED	89,80%	0,05%	55,13%	0,42%	90,04%	0,05%	56,30%	0,42%	90,53%	0,05%	56,71%	0,42%	90,71%	0,05%	56,78%	0,44%
PAN	95,83%	0,05%	42,59%	0,12%	95,83%	0,05%	42,59%	0,12%	92,00%	0,06%	42,59%	0,12%	96,00%	0,05%	43,64%	0,12%
STE	100,00%	0,00%	30,00%	0,07%	100,00%	0,00%	30,00%	0,07%	100,00%	0,00%	30,00%	0,07%	100,00%	0,00%	30,00%	0,07%
AL+ME+MK+RS+XK	100,00%	0,00%	41,67%	0,08%	100,00%	0,00%	41,67%	0,08%	93,75%	0,04%	41,67%	0,08%	100,00%	0,00%	43,24%	0,08%
AT + CH + LI	94,59%	0,07%	66,04%	0,14%	94,59%	0,07%	66,04%	0,14%	94,59%	0,07%	66,04%	0,14%	94,59%	0,07%	66,04%	0,14%
BA + HR + SI	90,00%	0,06%	58,06%	0,10%	90,00%	0,06%	58,06%	0,10%	90,00%	0,06%	58,06%	0,10%	85,71%	0,07%	58,06%	0,10%
BE + LU + NL + DK	94,20%	0,14%	63,73%	0,28%	94,29%	0,14%	64,71%	0,28%	93,15%	0,15%	65,39%	0,28%	94,59%	0,13%	66,67%	0,28%
BG	75,00%	0,07%	50,00%	0,08%	75,00%	0,07%	50,00%	0,08%	75,00%	0,07%	50,00%	0,08%	75,00%	0,07%	50,00%	0,08%
CZ + SK	91,43%	0,07%	68,09%	0,12%	88,89%	0,08%	68,09%	0,12%	86,49%	0,08%	66,67%	0,12%	86,49%	0,08%	66,67%	0,12%
DE	93,94%	0,10%	64,88%	0,32%	93,53%	0,11%	65,12%	0,32%	93,14%	0,11%	64,91%	0,32%	93,66%	0,11%	63,78%	0,35%
EE + LT + LV	100,00%	0,00%	37,50%	0,08%	100,00%	0,00%	37,50%	0,08%	100,00%	0,00%	37,50%	0,08%	100,00%	0,00%	37,50%	0,08%
EL	82,61%	0,06%	57,58%	0,08%	82,61%	0,06%	57,58%	0,08%	83,33%	0,06%	57,14%	0,08%	87,50%	0,05%	58,33%	0,08%
ES	87,01%	0,05%	48,31%	0,40%	87,65%	0,05%	50,47%	0,40%	87,65%	0,05%	50,47%	0,40%	88,89%	0,04%	50,46%	0,39%
FI	100,00%	0,00%	32,00%	0,06%	100,00%	0,00%	32,00%	0,06%	100,00%	0,00%	36,00%	0,06%	100,00%	0,00%	36,00%	0,06%
FR	92,81%	0,07%	50,72%	0,24%	92,91%	0,07%	51,10%	0,24%	93,15%	0,07%	52,64%	0,24%	93,24%	0,07%	52,33%	0,31%
HU	93,33%	0,06%	38,89%	0,11%	93,33%	0,06%	38,89%	0,11%	93,33%	0,06%	38,89%	0,11%	93,33%	0,06%	38,89%	0,11%
IE + UK	96,08%	0,06%	65,62%	0,29%	94,29%	0,07%	64,98%	0,29%	93,52%	0,08%	66,30%	0,29%	93,52%	0,08%	63,25%	0,37%
IS	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%
IT	96,75%	0,06%	54,32%	0,51%	96,03%	0,07%	54,98%	0,51%	96,88%	0,06%	55,84%	0,51%	96,90%	0,06%	56,03%	0,51%
NO	100,00%	0,00%	45,00%	0,03%	100,00%	0,00%	45,00%	0,03%	100,00%	0,00%	45,00%	0,03%	100,00%	0,00%	45,00%	0,03%
PL	80,33%	0,10%	53,85%	0,12%	80,33%	0,10%	53,85%	0,12%	79,69%	0,10%	55,44%	0,12%	78,46%	0,10%	55,44%	0,12%
PT	92,86%	0,08%	54,17%	0,16%	93,10%	0,08%	56,25%	0,16%	93,10%	0,08%	56,25%	0,16%	96,55%	0,06%	57,15%	0,15%

	2006				2009				2012				2015			
	User	CI95%	Prod	CI95%												
RO	100,00%	0,00%	35,82%	0,08%	100,00%	0,00%	35,82%	0,08%	100,00%	0,00%	35,82%	0,08%	100,00%	0,00%	35,82%	0,08%
SE	100,00%	0,00%	25,16%	0,64%	100,00%	0,00%	25,16%	0,64%	100,00%	0,00%	29,36%	0,64%	100,00%	0,00%	29,36%	0,64%
TR	83,08%	0,03%	47,08%	0,44%	81,8%	0,0%	47,1%	0,4%	81,16%	0,03%	47,99%	0,44%	79,17%	0,04%	47,62%	0,43%

#### 4.4. IMD2012 plausibility analysis correspondence analysis

One reason for the lower correspondences shown above is the arbitrary decision between urban and non-urban being imposed by the 30% threshold. Therefore, a point where the reference data is 30 % and the map density is 29 % will not correspond and vice versa. To cope with this situation and incorporate a level of plausibility onto the results the reference data were reprocessed allowing the interpreter to assess whether the mapped data was plausible.

The results in Table 4-4 using the plausibility analysis show considerable improvement in the correspondence results compared to the target accuracies of 90 % and the results of the blind interpretation (Table 4-3). The plausibility approach resulted in an improvement in the thematic accuracies recorded for all regions as expected. After the plausibility analysis, over 60% of the accuracy metrics exceeded the 90 % minimum accuracy requirement and a further 13% were with 5 % of the requirement. The range of changes are from 0 % to 70 % with a large amount of variability and with producer's accuracy dominating. For the BRME regions Steppic has the smallest and greatest change, but this may be influenced by the relatively small extent and the impact of a small number of plausibility changes. The Baltic States and Romania have the largest changes by country therefore suggesting a geospatial component to the quality of the results.

Table 4-4: A summary of the correspondence results for the plausibility analysis for the reprocessed 2006, 2009 and 2012 data and the 2015 results. Green cells exceed the 90 % minimum accuracy requirement, orange cells are within 5% and red cells fall more than 5% short.

	2006				2009				2012				2015			
	User	CI95%	Prod	CI95%												
European All	96,19%	0,04%	84,57%	0,15%	95,34%	0,04%	84,41%	0,15%	94,65%	0,05%	84,75%	0,17%	95,41%	0,04%	84,50%	0,17%
ALP	100,00%	0,00%	90,91%	0,02%	100,00%	0,00%	91,07%	0,02%	100,00%	0,00%	92,86%	0,02%	100,00%	0,00%	92,86%	0,02%
ANA	80,00%	0,03%	86,96%	0,02%	76,92%	0,03%	86,96%	0,02%	75,00%	0,03%	87,50%	0,02%	78,57%	0,03%	88,00%	0,02%
ARC	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%
ATL	98,65%	0,04%	82,69%	0,21%	97,68%	0,05%	82,32%	0,21%	96,14%	0,07%	82,75%	0,20%	97,76%	0,05%	82,40%	0,20%
BLS	75,00%	0,04%	75,00%	0,04%	75,00%	0,04%	75,00%	0,04%	75,00%	0,04%	75,00%	0,04%	80,00%	0,04%	80,00%	0,04%
BOR	100,00%	0,00%	64,60%	0,49%	100,00%	0,00%	64,60%	0,49%	100,00%	0,00%	71,52%	0,49%	100,00%	0,00%	71,52%	0,49%
CON	96,11%	0,06%	88,97%	0,09%	95,15%	0,06%	88,39%	0,10%	94,26%	0,07%	88,04%	0,18%	94,79%	0,07%	87,95%	0,18%
MAC	100,00%	0,00%	50,00%	0,23%	100,00%	0,00%	50,00%	0,23%	100,00%	0,00%	50,00%	0,23%	100,00%	0,00%	50,00%	0,23%
MED	93,73%	0,04%	81,85%	0,07%	93,10%	0,04%	82,37%	0,07%	93,56%	0,04%	82,33%	0,07%	93,68%	0,04%	82,09%	0,07%
PAN	100,00%	0,00%	92,31%	0,06%	100,00%	0,00%	92,31%	0,06%	100,00%	0,00%	92,59%	0,06%	100,00%	0,00%	89,29%	0,07%
STE	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%
AL+ME+MK+RS+XK	100,00%	0,00%	78,95%	0,06%	100,00%	0,00%	78,95%	0,06%	100,00%	0,00%	80,00%	0,06%	100,00%	0,00%	80,00%	0,06%
AT + CH + LI	100,00%	0,00%	92,50%	0,08%	100,00%	0,00%	92,50%	0,08%	100,00%	0,00%	92,50%	0,08%	100,00%	0,00%	92,50%	0,08%
BA + HR + SI	90,00%	0,06%	90,00%	0,06%	90,00%	0,06%	90,00%	0,06%	90,00%	0,06%	90,00%	0,06%	85,71%	0,07%	90,00%	0,06%
BE + LU + NL + DK	97,10%	0,10%	85,90%	0,21%	97,14%	0,10%	86,08%	0,21%	98,63%	0,07%	88,89%	0,19%	98,65%	0,07%	89,02%	0,19%
BG	100,00%	0,00%	88,89%	0,05%	100,00%	0,00%	80,00%	0,06%	100,00%	0,00%	80,00%	0,06%	100,00%	0,00%	80,00%	0,06%
CZ + SK	97,14%	0,04%	91,89%	0,07%	94,44%	0,06%	91,89%	0,07%	91,89%	0,07%	91,89%	0,07%	91,89%	0,07%	91,89%	0,07%
DE	95,96%	0,09%	85,97%	0,15%	94,53%	0,10%	85,20%	0,15%	93,63%	0,11%	83,28%	0,25%	95,12%	0,09%	83,57%	0,25%
EE + LT + LV	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%
EL	86,96%	0,05%	71,43%	0,07%	86,96%	0,05%	71,43%	0,07%	87,50%	0,05%	72,41%	0,07%	87,50%	0,05%	72,41%	0,07%
ES	92,21%	0,04%	71,00%	0,06%	91,36%	0,04%	72,55%	0,06%	92,59%	0,04%	72,12%	0,06%	93,83%	0,03%	71,70%	0,06%
FI	100,00%	0,00%	72,73%	0,05%	100,00%	0,00%	72,73%	0,05%	100,00%	0,00%	81,82%	0,05%	100,00%	0,00%	81,82%	0,05%
FR	96,40%	0,05%	85,90%	0,10%	95,74%	0,06%	84,37%	0,10%	93,15%	0,07%	85,53%	0,10%	95,95%	0,06%	86,59%	0,10%
HU	100,00%	0,00%	93,75%	0,06%	100,00%	0,00%	93,75%	0,06%	100,00%	0,00%	93,75%	0,06%	100,00%	0,00%	88,24%	0,07%
IE + UK	100,00%	0,00%	81,37%	0,30%	99,05%	0,03%	81,67%	0,30%	97,22%	0,05%	81,81%	0,29%	97,22%	0,05%	79,94%	0,29%
IS	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%	100,00%	0,00%
IT	99,19%	0,03%	89,05%	0,11%	98,41%	0,04%	89,86%	0,10%	99,22%	0,03%	90,71%	0,10%	99,22%	0,03%	90,78%	0,10%
NO	100,00%	0,00%	69,23%	0,02%	100,00%	0,00%	69,23%	0,02%	100,00%	0,00%	69,23%	0,02%	100,00%	0,00%	64,29%	0,02%
PL	91,80%	0,07%	93,33%	0,06%	91,80%	0,07%	93,33%	0,06%	89,06%	0,07%	93,44%	0,06%	89,23%	0,07%	93,55%	0,06%

	2006				2009				2012				2015			
	User	CI95%	Prod	CI95%												
PT	100,00%	0,00%	84,85%	0,11%	96,55%	0,06%	84,85%	0,11%	100,00%	0,00%	85,30%	0,10%	100,00%	0,00%	85,30%	0,10%
RO	100,00%	0,00%	96,00%	0,03%	100,00%	0,00%	96,00%	0,03%	100,00%	0,00%	96,00%	0,03%	100,00%	0,00%	96,00%	0,03%
SE	100,00%	0,00%	53,70%	0,66%	100,00%	0,00%	53,70%	0,66%	100,00%	0,00%	62,65%	0,66%	100,00%	0,00%	62,65%	0,66%
TR	87,69%	0,03%	87,69%	0,03%	86,36%	0,03%	87,69%	0,03%	84,06%	0,03%	87,88%	0,03%	86,11%	0,03%	86,11%	0,03%

## 5. Thematic Accuracy IMCC

The imperviousness change products (IMC0609, IMC0912 & IMC1215) show the changes in imperviousness density between the two reference years including the direction of change.

For the thematic accuracy assessment of these changes in imperviousness density the results recorded in the classified imperviousness change products (IMCC2006-2009, IMCC2009-2012 & IMC2012-2015) were simplified to:

- 0 – No change with zero imperviousness
- 1 – Change in imperviousness
- 10 – No change with imperviousness greater than zero

The reference data from the plausibility analysis were then processed to match the simplified change classes and a correspondence analysis performed on the pan-European, BRME and country / country group regionalisations (Table 5-1).

It can be seen that less than one third of the results reached the 90 % thematic accuracy requirement set in the technical specifications, even when a 5% allowance was made. The 2006-2009 results were the poorest with 2009-2012 coming out the best but still only producing just under one third of the results with user's and producer's accuracy greater than 85 %.

The pan-European results seemed to be around 60 % accuracy with these values representing an average from the highly variable results for the different regionalisations. 2006-2009 and 2009-2012 are reasonably, 2012-2015 shows a dramatic reduction in producer's accuracy showing an increase in omissions.

The accuracy results ranged from unavailable and 0 % to 100 % due to the lack of or limited number of mapped change and the ability to identify viable changes in the reference data. These cases were often associated with the more unique regions such as the Arctic and small areas such as Macaronesian so they were not representative of the datasets as a whole.

The results are highly variable across the regionalisations, but some regions and countries do show consistently good results or a trend over time. For instance, the Pannonian region and Hungary consistently almost reach or exceed the requirement for accuracy. Some countries show improvement over time (e.g. Bulgaria and Romania) while other show declines.

The relationship between user's and producer's accuracy is also highly variable with no pattern or balance between the two values dominating. Therefore there is a very mixed picture of the pattern of omissions and commissions for the changes.

Table 5-1: A summary of the correspondence results for the plausibility analysis for the classified imperviousness change IMCC2006-2009, IMCC2009-2012 and IMCC2012-2015 results. Green cells exceed the 90 % minimum accuracy requirement, orange cells are within 5% and red cells fall more than 5% short.

	IMCC2006-2009		IMCC2009-2012		IMCC2012-2015	
	User	Prod	User	Prod	User	Prod
European All	56.9%	67.7%	52.7%	60.1%	61.9%	37.6%
ALP	68.2%	71.5%	44.5%	43.9%	94.3%	27.2%
ANA	59.4%	42.6%	77.1%	73.2%	75.3%	50.2%
ARC	10.0%	100.0%	51.6%	100.0%	0.0%	
ATL	67.8%	72.4%	49.9%	70.7%	52.9%	32.2%
BLS	74.6%	79.1%	100.0%	23.3%	95.0%	68.9%
BOR	38.1%	48.0%	36.6%	83.8%	85.4%	16.0%
CON	48.5%	58.3%	54.3%	55.4%	64.6%	39.6%
MAC	19.1%	100.0%	100.0%	100.0%	2.5%	100.0%
MED	56.1%	73.9%	54.9%	51.8%	52.6%	34.1%
PAN	92.6%	88.3%	93.8%	94.2%	93.9%	97.6%
STE	58.3%	100.0%	87.5%	100.0%	78.5%	100.0%
AL+ME+MK+RS+XK	66.7%	59.4%	97.7%	87.9%	92.4%	96.3%
AT + CH + LI	61.9%	96.2%	79.8%	56.4%	96.8%	52.4%
BA + HR + SI	95.1%	97.2%	56.1%	96.6%	65.1%	9.6%
BE + LU+ NL + DK	76.5%	51.6%	36.9%	73.0%	52.6%	36.5%
BG	53.3%	53.5%	96.7%	93.6%	92.5%	96.8%
CZ + SK	45.1%	47.2%	60.3%	59.1%	90.2%	92.8%
DE	49.0%	82.5%	45.8%	29.9%	48.1%	21.5%
EE + LT + LV	20.9%	90.3%	53.3%	96.6%	64.8%	8.0%
EL	24.5%	24.6%	71.4%	70.4%	16.2%	88.9%
ES	61.4%	86.5%	41.9%	44.3%	18.0%	23.3%
FI	67.2%	92.5%	65.4%	78.9%	66.7%	2.9%
FR	61.7%	82.3%	66.9%	66.3%	52.8%	38.1%
FR DOMs						
HU	100.0%	90.5%	89.8%	91.1%	90.9%	96.4%
IE + UK	81.7%	99.0%	53.0%	85.6%	68.5%	32.8%
IS	10.0%	100.0%	51.6%	100.0%	0.0%	
IT	51.4%	63.6%	39.8%	67.0%	66.0%	15.8%
NO	18.2%	80.9%	13.7%	100.0%	70.0%	8.6%
PL	64.0%	26.3%	66.6%	87.7%	56.6%	67.0%
PT	19.4%	33.0%	31.6%	31.1%	33.7%	36.4%
RO	68.9%	81.1%	53.4%	92.0%	87.5%	98.9%
SE	15.8%	29.6%	9.7%	91.9%	92.1%	52.5%
TR	67.8%	65.0%	79.7%	49.1%	82.6%	45.0%

## 6. Conclusions and recommendations

This report represents a thorough examination of the IMD and IMC layers for all four reference years. It provides an independent validation assessment of the performance of the products against their design specifications with blind interpretations and plausibility analyses putting clear boundaries on the thematic quality of the products being made available to the wider community.

The review of the specifications of the products in chapter 3 shows a very close alignment to the design requirements. There are still a few short comings with the products including the documentation and metadata which have been noted. The map data currently does not include details on the image data used for the production (e.g. time stamps, sensor, ancillary information etc.) which would be extremely useful when trying to interpret the results of studies such as this.

The scatterplots for the IMD product presented in section 4.1 show the overall situation for the layers across Europe. The majority of the points analysed are within 20 % of the best fit line, but there is some variability in the distribution depending on the actual sealing level. From the regression results in section 4.1 it can be seen that for the larger regionalisations the coefficient of determination tends to be around 0.8, but there is variability between biogeographical regions and countries. The variability of the results for the biogeographical regions would indicate an underlying landscape level effect on the results which was outside the control of the producers.

From the regression slope results there is general trend that the IMD products are under estimates relative to the actual imperviousness values as estimated by the validation team. This means that potentially different thresholds should be applied to map IMD based density values to urban areas and thus better match the validation data when producing the urban area layer.

The thematic accuracy results used an arbitrary 30 % threshold for the conversion of IMD and reference data to urban areas. The blind interpretation (section 4.3) produced results that did not fully meet the requirements of 90 % minimum thematic accuracy in the specification. The results are generally in line with specifications for commission errors, but are outside the specifications for omission errors. However, the commission errors are easier to identify and thus correct than omission errors. Some thematic accuracy results do exceed the proposed 90 % target accuracy.

The results for the thematic accuracy of the changes fell short of the target requirement of 90 % at the pan-European level and for the majority of the regionalisations. Nevertheless, the change accuracy results are much improved compared to the previous assessment performed as part of the 2012 production. There were no clear patterns in the levels of accuracy or the relative occurrence of omissions and commissions across the regionalisations. The highly variable nature and the presence of extreme values would suggest relatively low levels of change which are not being adequately detected by the validation process at present.