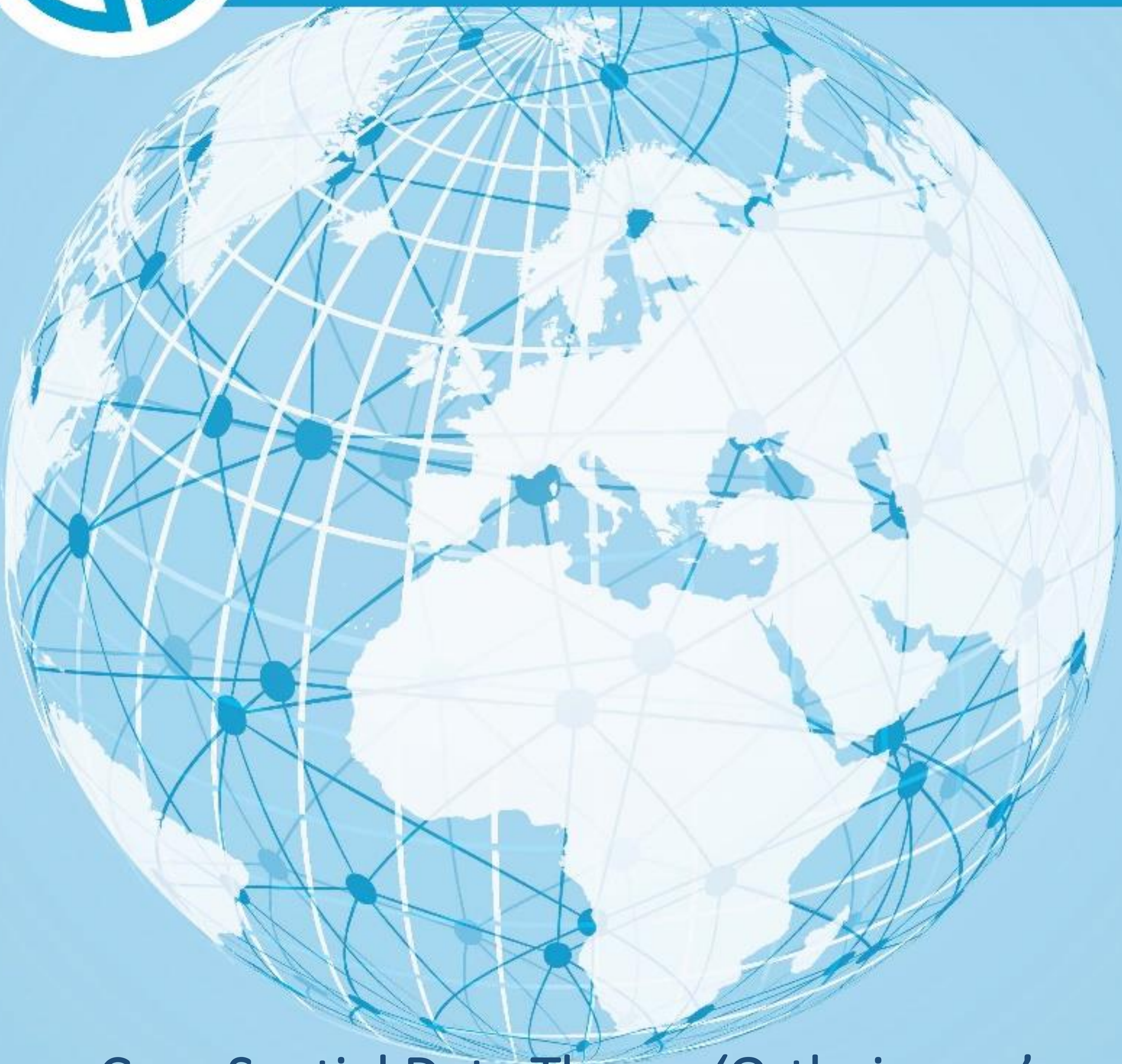
UN-GGIM EUROPE

UNITED NATIONS COMMITEE OF EXPERTS ON GLOBAL GEOSPATIAL INFORMATION MANAGEMENT



Core Spatial Data Theme 'Orthoimage' Recommendation for Content

Working Group A - Deliverable of Task 1.b

Version 1.0 - 2019-04-19

Version History

Version number	Date	Modified by	Comments
1.0	19/04/2019	WG A	Consolidated draft, for review by geographical and statistical community

Warning: in the following parts of this document, the paragraphs written in grey e.g. "This document has annexes containing more detailed explanations " are common to all core spatial data themes; they aim to provide context and objectives of core data. The paragraphs written in black are specific to core spatial data theme Orthoimage.

Content

1 Executive Summary

In September 2015 the countries of the United Nations adopted the 2030 Agenda for Sustainable Development; a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years. The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda are supported by 169 targets and 230 indicators.

Geospatial data supports the measuring, achieving and monitoring of many of the goals and targets set by the 2030 Agenda. The 2030 Agenda demands new data acquisition and integration approaches to improve the availability, quality, timeliness and disaggregation of data. Goal 17 explicitly emphasizes the need for developing capacities and partnerships. In this context the success of the 2030 Agenda depends on senior administrators owning and leading the geospatial efforts in their respective countries.

In Europe, building on the INSPIRE Directive redirecting the focus on a cohesive spatial data infrastructure without gaps in content and discrepancies in quality, stakeholders are working on geospatial standardization and increasing richness of data through Core Data Recommendations for Content that correspond to the first phase of WGA work program. Core data is primarily meant for fulfilling the common user requirements related to SDGs in Member States and European institutions.

An orthoimage is a raster image that has been geometrically corrected ("orthorectified") to remove distortion caused by differences in elevation, sensor tilt and, optionally, by sensor optics. Orthoimagery is part of the basic geographic equipment of a country. It is widely used for visualisation purposes, for deriving thematic data (such as land cover) or as geometric reference.

Several products are necessary to cover the wide range of user requirements. The main priority is the production of a reference orthoimage on whole land territory, with good visual aspect, fine spatial resolution (from 20 cm to 1 m) and consistent accuracy; this reference orthoimage should be produced every 3 years. This should be complemented by an orthoimage of grosser spatial resolution but of higher temporal frequency, to address the derivation of thematic data use case. In practice, this may be achieved through the production and delivery of the orthoimages from the Copernicus Sentinel-2 program. In urban areas, there may be interest, for some specific use cases, to produce a very fine resolution orthoimage (ground pixel 10 cm or better).

These orthoimages should be delivered with a set of mosaic elements documenting the date of source images (as defined in INSPIRE) and in popular image formats including georeferencing.

Once produced, the orthoimages should be kept accessible to users as they provide very valuable information on the landscape evolution. Orthoimages offer a quantitative representation of the past and/or present condition of the land surface.

2 Foreword

2.1 Document purpose and structure

2.1.1 Purpose

This document provides the main characteristics of core data for theme Orthoimage with focus on the recommendation for content. This document aims to help decision makers (from governments, data producers, national coordination bodies, etc.) to define their policy regarding the improvement of existing data and production of new geospatial data. It addresses digital data.

This document has Annexes containing more detailed explanations targeting the technical people who will be in charge of implementing or adapting core data recommendations (e.g. for production purpose, as source of other standards, etc.).

2.1.2 Structure

The executive summary synthesizes the main conclusions of the Working Group A (WG A) process and results to develop the recommendation for content. It is meant mainly for high level decision makers.

The foreword reminds the general context of core data, the first step achieved by WG A (i.e. selecting core data themes), and it explains the general principles set by WG A to develop the recommendations for content of core data specifications for all selected themes.

The ‘recommendation for content’ document itself includes four chapters:

- Overview: it provides the general scope of the theme and describes the main use cases addressed;
- Data content: it provides the main characteristics of the recommended content, such as the list of core features and attributes (for vector data), as well as data capture and quality rules;
- Other recommendations: e.g. Coordinate Reference System, Metadata, Delivery;
- Considerations for future: this chapter addresses some key trends or significant user requirements that cannot be considered as core today but that might be considered in future.

The ‘recommendation for content’ document is meant for medium level decision makers. It is written in natural and not too technical language.

The technical explanations included in annexes describe the relationship between the recommendation for content and the corresponding INSPIRE specification, and contain any other appropriate information useful for this theme.

2.2 Core data context

2.2.1 Rationale for core data

The following background of harmonised pan-European data was identified.[1]

Authoritative geospatial data are used to support both the implementation of public policies and the development of downstream services. Moreover, geospatial data are required to be homogenous to enable the implementation of public policies in a coherent and coordinated way among countries and at regional or global level. Likewise, significant opportunities exist if services developed by industry can be exploited without requiring country specific adaptation.

The INSPIRE Directive has set up the legal and technical framework for harmonisation of the existing data related to the themes in annexes I, II and III. INSPIRE specifications provide common data models that ensure a first step towards interoperability, however ensuring homogeneous content is outside their scope, as they contain no indication about levels of detail, very few recommendations about quality, and as most features and attributes are "voidable", i.e. to be supplied if available or derivable at reasonable cost.

This background led the UN-GGIM: Europe Regional Committee to setup in 2014 the Working Group A on Core Data to deal with core data content and quality, production issues, funding and data availability.

Recommendations for content of core data will complement INSPIRE data specifications by defining the priorities on the core content that is encouraged to be made available in Europe in order to fulfil the main user requirements that are common to many countries, with focus on the SDG related ones.

Core data availability may be ensured either through upgrading of existing data when feasible or through production of new data when necessary.

2.2.2 Core data scope

In its first phase, WG A selected core data themes according to the following criteria: core data is the geospatial data that is the most useful, either directly or indirectly, to analyse, to achieve and to monitor the Sustainable Development Goals.

Among the 34 INSPIRE data themes, 14 have been considered as core including theme Orthoimage.

More information about the selection process and results may be found in document 'Core Data Scope - Working Group A - First Deliverable of Task 1.a - Version 1.2' on http://un-ggim-europe.org/content/wg-a-core-data

[1] Extract from the Report by the Preparatory Committee on the establishment of the UN-GGIM: Europe Regional Committee, European Commission Ref. Ares(2014)1491140 - 09/05/2014.

2.3 Document objectives and principles

2.3.1 Encouraging content availability

This deliverable provides recommendations for national governments and data producers, aiming to help them to define their priorities for enriching existing data or producing new data. This deliverable is meant mainly for data producers, however it defines the recommended result and target but not the production process.

2.3.2 Complementing INSPIRE

Core data specifications are built upon INSPIRE data specifications. On one hand, they often simplify INSPIRE by selecting core feature types and attributes and by restricting or clarifying the scope; On the other hand, they enrich INSPIRE by recommending specific levels of detail, quality rules and sometimes data model extensions. Besides, the INSPIRE common terminology is thoroughly used for naming core features and attributes.

Regarding the levels of detail, the ELF (European Location Framework) project terminology has been used. The ELF levels of detail are the following: Global, Regional, Master level 2, Master level 1, Master level 0. These terms are defined in the glossary.

Regarding delivery, core data may be supplied according to several ways. It is expected that, very often, the core data recommendations will be used to enrich and upgrade existing products. In this case, core data will be available through these improved products. Core data may also be delivered through INSPIRE conditions (specifications and services).

2.3.3 Status of core data recommendations

This document contains recommendations that are not legally binding. However, some recommendations are more important than others. This order is indicated as follow:

Core Recommendation X

It is first priority recommendation, considered as both necessary and achievable in principle. Ideally, it should encourage involved stakeholders to launch short-term actions (typically within a couple of years).

Core recommendations are usually addressing only technical aspects and are meant for the organisations in charge of producing this theme. The set of core recommendations defines the basic expectations on core data.

Good Practice X
It is second priority recommendation; if adopted, it will provide significant added value to core data; it indicates a relevant trend to be adopted as much as possible. It encourages involved stakeholders to take these recommendations into account in long term, if not possible in short term.

NOTE: some of these good practices may be quite easy to achieve and are already effective in some countries whereas some others may be more difficult to achieve. This is typically the case when these good practice recommendations involve other stakeholders in addition to the organisations in charge of producing this theme, and when they address not only technical aspects but also legal or organisational ones.

A “core data set” should contain the minimum data defined by the core recommendations (and ideally also by the good practices) of this deliverable but may of course contain more and/or better information.

2.4 Abbreviations

CRS	Coordinate Reference System
DSM	Digital Surface model
DTM	Digital Terrain Model
ELF	European Location Framework
GPS	Global Positioning System
LC	INSPIRE theme Land Cover
LU	INSPIRE theme Land Use
OI	INSPIRE theme Orthoimagery
SDG	Sustainable Development Goal
UN-GGIM	United Nations initiative on Global Geospatial Information Management
WG A	(UN-GGIM: Europe) Working Group on Core data

2.5 Glossary

2.5.1 Levels of detail

Global	Level of detail defined by ELF: data to be used generally at scales between 1: 500 000 and 1: 1 000 000, i.e. mainly at international level
Regional	Level of detail defined by ELF: data to be used generally at scales between 1: 100 000 and 1: 500 000; data mainly for national or regional (European or cross-border) actions.
Master level 2	Level of detail defined by ELF: data to be used generally at scales between 1: 25 000 and 1: 100 000); data mainly for regional (sub-national) actions.
Master level 1	Level of detail defined by ELF: data to be used generally at scales between 1: 5 000 and 1: 25 000; data mainly for local level actions.
Master level 0	Level of detail defined by ELF: data to be used generally at scales larger than 1: 5 000; typically, data at cadastral map level, mainly for local level actions.

NOTE: the above definitions are indicative; in practice, detailed data (Master levels) may also be required also by national, European or international users.

2.6 Reference documents

INSPIRE Data Specification on Orthoimagery– Technical Guidelines 3.1:
http://inspire.ec.europa.eu/id/document/tg/oi..

3 Overview

3.1 General scope

Definition: The *Orthoimage* data theme includes orthorectified image data of the Earth's surface, acquired from either satellite or airborne sensors. An orthoimage is a raster image that has been geometrically corrected ("orthorectified") to remove distortion caused by differences in elevation, sensor tilt and, optionally, by sensor optics. [from INSPIRE description]

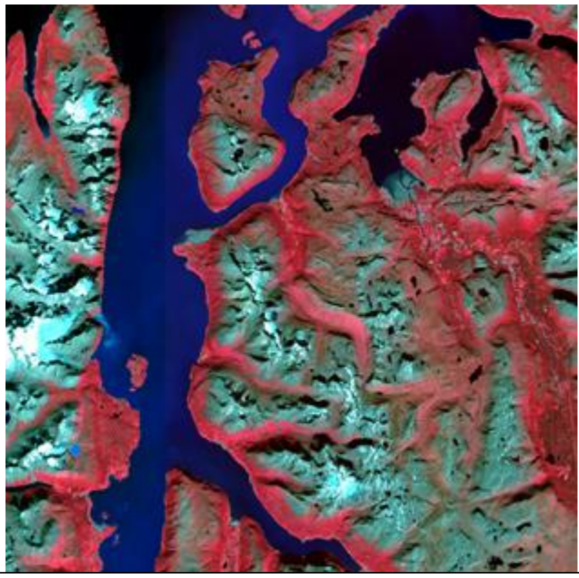
	
Orthoimage based on aerial photograph/image. Drammen, Norway.	Orthoimage based on Infrared band. False colours. - Copernicus Sentinel-2 Lyngen, Norway.

Figure 1: examples of orthoimages

Orthoimages may represent a view of a landscape or area, commonly based on air-born sensors or satellites as remote sensing. Different sensors record different fractions of radiation, visible light, infrared waved or radar. Combination of raw data from the sensors may be used to produce different kinds of products.

NOTE 1: The scope of this theme is very similar to the scope of INSPIRE theme Orthoimagery. It is limited to the representation of the Earth surface and therefore excludes imagery of the sea bed (from underwater sensors), imagery of oceanographic parameters, meteorological satellite imagery and terrestrial imagery.

However, not all the possible image sources listed by INSPIRE have been considered as relevant for core data (for more details, see clause 4.5).

More detailed comparison with INSPIRE is available in the annex A of this document.

NOTE 2: The production of an orthoimage coverage requires as source data a set of raster images, with relevant overlaps. In a first step, a Digital terrain Model is used to get the Z coordinate of each pixel of the orthoimage (terrain coordinates). In a second step, the mathematical function between the terrain coordinates and the image coordinates is computed using as input the position and orientation of the image sensor, homologous points between neighbour images and ground control points. Using the mathematical function mentioned above, the pixel is filled with the radiometry of corresponding point in the most relevant source image. Other processes may be added to get better visual aspect.

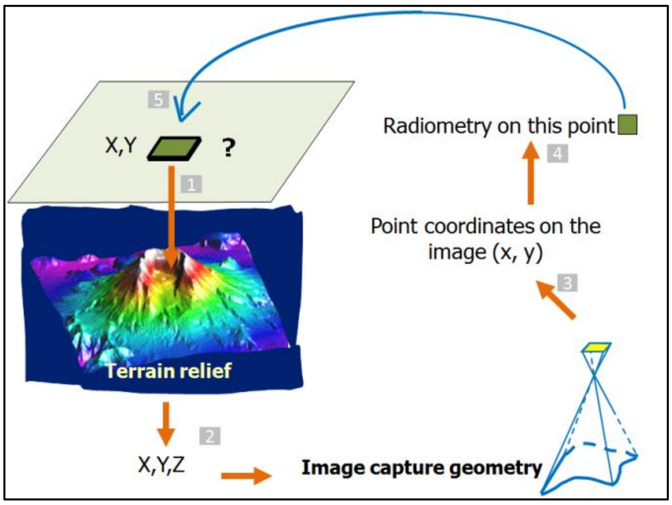


Figure 2: the orthorectification process.

3.2 Use cases

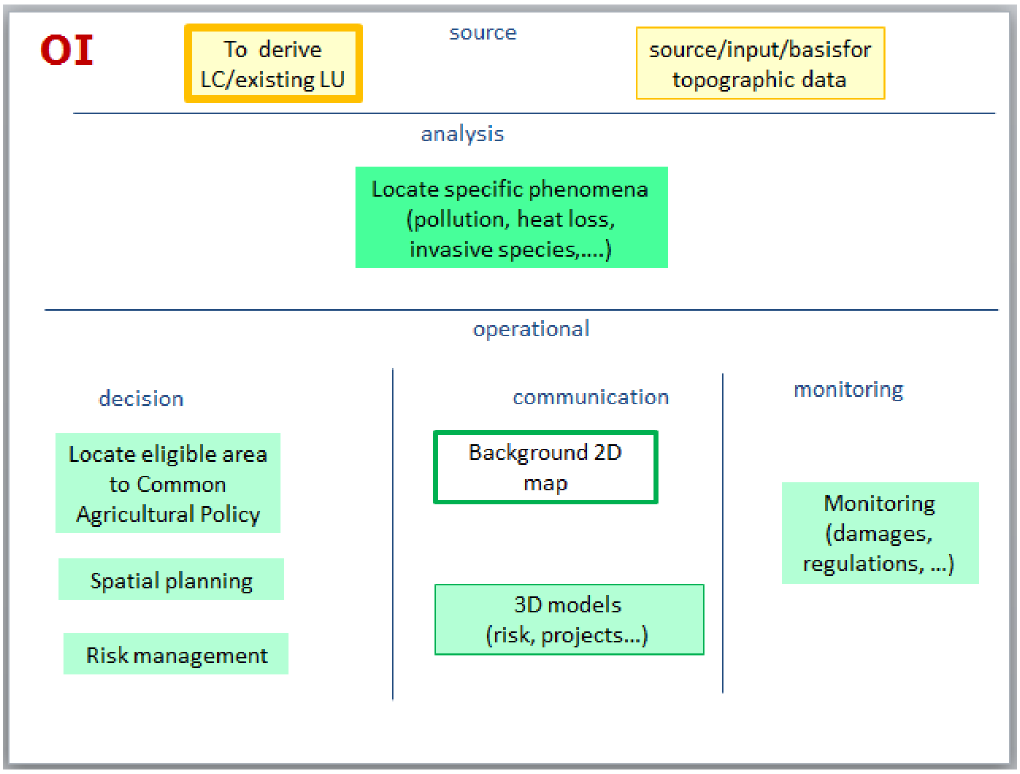


Figure 3: map of use cases for theme Orthoimage

Theme 'Orthoimagery' is part of the basic geographic equipment of a country; orthoimages are widely used as primary source data to derive land cover or existing land use data; they may also be used to plot main topographical assets either in the production or in the maintenance process: map updating and change detection are important uses of orthoimages (for instance, orthoimages are often used to detect missing buildings in topographic databases).

Orthoimages are also appreciated for communication purposes; orthophotos may replace maps (if some geographical names are added) or complement them as a main background layer; it is also quite common to wrap an orthoimage on a Digital Terrain Model.

Orthoimages provide a valuable description of the environment; used by thematic experts, they enable to understand the landscape, to locate and assess various phenomena (crops, health of trees, detection of archaeological remains, invasive species, habitats etc.). Taken at night, they allow detection of light pollution in cities or of heat losses in buildings.

In the operational phase, they are used by farmers and growers of the European Union to declare their agricultural and non-agricultural areas on a yearly basis within the framework of the Common Agricultural Policy.

Satellites enable images of the Earth to be taken very regularly, with high frequency. This makes satellite orthoimages of key interest in monitoring processes, e.g. to assess the damages caused by a disaster before deciding on compensations or to check if the environmental regulations are followed by farmers.

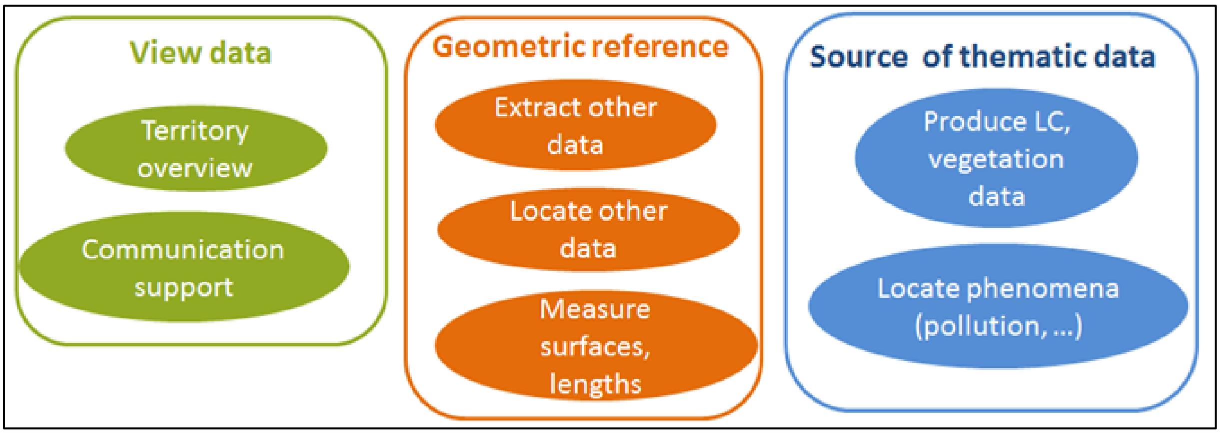


Figure 4: the main roles of orthoimage.

In a more functional approach, orthoimage products may be considered as playing three main roles:

- They are used for visualisation purposes as they provide to human beings a view of the territory that may be more intuitive and more attractive than other data representations (such as maps); they may be used in various communication supports (paper or digital, on line or off-line, 2D or 3D, alone or enriched by other data ...).
- They are used as a geometric reference, enabling to extract other data (e.g. vectorisation of roads), to locate other data (e.g. GPS points or tracks) or to measure surfaces, lengths, distances. These processes may be done manually by human beings or automatically by machines.
- They are used to extract thematic data, as a regular process (e.g. for production of land cover data or for monitoring vegetation) or in more specific cases (such as monitoring disasters or pollution impacts). These processes may be performed manually by human beings or automatically by machines, through automatic segmentation and classification.

4 Data content

4.1 Reference orthoimage (Master level 1)

4.1.1 Main characteristics

Core Recommendation 1

Member States should ensure the production and availability of an orthoimage with following characteristics:

- ground pixel size (spatial resolution): from 20 cm to 1 m

-spectral resolution: Red Green Blue + Near Infrared

- frequency: 3 years or better

- planimetric accuracy: better than 5 m

- a good visual aspect

- geographic extent: whole country (terrestrial part + buffer on coastal waters)

NOTE 1: This reference orthoimage is considered as part of the basic geographic equipment of a country. It may be used, in a consistent way, with large scale vector data (Master level 1). It may even be used with Master level 0 vector data in most parts of the country, e.g. in rural areas. It may be used for a wide range of use cases, as a geometric reference or for visualisation purposes.

NOTE 2: The core recommendations express minimum common requirements. In practice, core recommendation 1 corresponds more or less to the current practice of most European Member States. However, the trend is to produce highly resolute and accurate reference orthoimage, typically with ground pixel size better than 50 cm and accuracy around 1 m. This trend should be encouraged.

NOTE 3: The buffer size on coastal waters may depend of local specificities; 200 m is considered as reasonable average value.

NOTE 4: The 3 years frequency is a minimum value corresponding to user requirements. However, it should be recognised that aerial photography in remote mountainous areas is costly and difficult due to weather problems. A lower frequency may be accepted as an exception in these areas.

NOTE 5: Coastal areas are of great interest for environment and therefore relevant orthoimages on these areas are required. In practice, the coastal orthoimage should have the same main characteristics as the reference orthoimage but it should ensure, in addition, that the shore is perfectly visible (no cloud, images taken at lower water tides, with successive images following the shoreline). In case the shore represents significant areas from the country (e.g. a long, or deeply indented, coast with important tidal effects), the production of coastal orthoimages may require specific flights for collecting the source images.

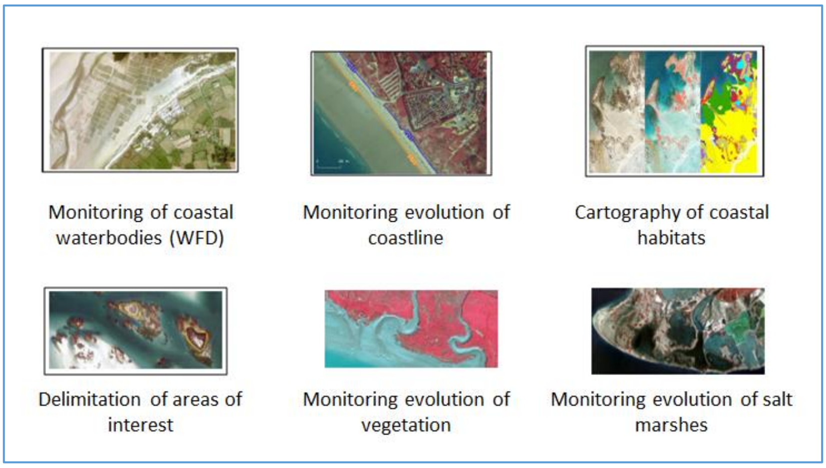


Figure 5: some use cases related to coastal areas

4.1.2 Quality

4.1.2.1 Visual aspect

Good visual aspect is a general preconisation of Core recommendation 1. Visual aspect covers two main topics: the quality of source images and the quality of the production process (ortho-rectification and mosaicking)

Core Recommendation 2
The reference orthoimage should be produced from images ensuring good visibility: absence of clouds, limited shadows and good radiometric dynamic range.

NOTE 1: In practice, to limit long shadow effects, as a general rule, source images should be taken in spring or in summer (northern hemisphere). In addition, vegetation as captured on spring or summer images will make the resulting orthoimage more attractive for visualisation purposes and for some remote sensing applications. Of course, the best time for image collection depends on the country location and is up to each data producer. It should also be recognised that leaf-off conditions are offering advantages e.g. for mapping in forests although the image is not as appealing as green vegetation.

NOTE 2: According to the general scope, source images might be digital images from airborne or satellite sensors or scanned films. For reference orthoimage, scanned films are not considered as relevant: their quality is not as good as natively digital images and anyway, their use is no longer in practice, all producers employing (natively) digital images (except for historical documentation, requiring scanning of analogical photographs, see §6.1 below, production of historical orthoimages). Digital images from airborne sensors offer, for human beings, better radiometric information than satellite images and should be preferred, if affordable.

Good Practice 1
Great care has to be taken to ensure an intuitive landscape reading and the continuity of major structural topographic elements.

NOTE 1: The sensor's radiometric response doesn't only depend on the landscape but is also influenced by the conditions of image capture (e.g. date and time). The visual discontinuities between images should be minimised as much as possible, through radiometric or colorimetric equalizing between source images and by delineating, as much as possible, relevant and discreet mosaicking lines.

In the following illustration, the two source images used to produce the orthoimage mosaic were taken at different times. The different mosaicking lines result in different aspects of the orthoimage mosaic.

	
The radiometric response is quite different, though the landscape feature is the same (a ploughed field). The initial mosaic line cuts across the field, giving the misleading impression that the field is made of two very different parts.	The mosaic line has been displaced: it is now conforming to the limit of the field. The ploughed field that has a (more or less) homogeneous aspect in the real world shows now a consistent spectre on the orthoimage. Such processing contributes to the intuitive reading of the landscape shown by the mosaic, no longer hampered by non-geographical, purely instrumental, colorimetric discontinuities.

Figure 6: choice of relevant mosaic lines

However, in the case of large, homogeneous, real world areas (e.g. waterbodies and sea, large fields, extended forests), it is not always possible to “hide” the mosaicking lines along natural topographic limits. Smoothing the colorimetric step across the mosaicking line by computing some average value of the pixels in the overlapping parts of the images is not advised. Both for visual and automated interpretation, it is better to keep the native value of one of the source images.

NOTE 2: Major structural topographic elements include linear elements such as roads, railways, watercourses. Limits of fields must also be considered and continuity should also be ensured, as much as possible, on agricultural parcels. Geometric continuity is mainly ensured by using relevant terrain data in the ortho-rectification process. Typically, a DTM with a 10m x 10m grid size and an accuracy of around 2 m, where bridges are either rendered as “terrain surface” (such as in a Digital Surface Model) or added as an extra altitudinous level would be adapted to the production of reference orthoimage.

Figure 7: an example of discontinuity on road network (to be avoided!)

4.1.2.2 Geometric criteria

The main criteria are spatial resolution (also called Ground Sampling Distance) and geometric (also called planimetric) accuracy of the orthoimage. They are already addressed in the description of the core characteristics of the reference orthoimage.

4.1.2.3 Temporal aspects

Users should be given the opportunity to benefit from relatively "fresh" orthoimage data, available soon after the source images have been captured.

Good Practice 2

As much as possible, the production process should be organised in such a way that it takes six months or less between the date when the source images are captured and the date when the orthoimage data is made available to users.

NOTE 1: Typically, for source images taken by spring or early summer of a given year in the northern hemisphere (e.g. June of year n), the resulting orthoimage should be available before the end of the same year (e.g. by December of year n).

4.2 High frequency orthoimage (Master level 2)

High frequency orthoimages are required at least in the following cases: to extract information about land cover, mainly for monitoring vegetation evolutions, and to get information in case of emergency events (disasters, pollution, etc).

In practice, most of these requirements are covered by the orthoimages issued from the Sentinel-2 images of the Copernicus program. These images have a spatial resolution of 10m, a rich radiometric range (13 bands) and a high frequency (visit every 5 days) and are available as open data.

These orthoimages still require technical and experimented skills for use and interpretation by users: rectification is performed by image (no mosaicking), ground information may be occluded by clouds, the 13 radiometric bands may be easily processed by machines but not so easily by human beings. The European Commission has launched a specific initiative (Copernicus Sentinel-2 Global Mosaic) to set up services aiming at generating customised orthoimages, typically by making a continuous view from the selection of the available pixels, without clouds and close to the date required by the user.

Good Practice 3
The efforts to produce and to make more user-friendly the orthoimages coming from the Sentinel-2 program should be continued and encouraged.

NOTE 1: In most cases, orthoimages from Sentinel-2 images represent a good potential minimum common solution for European countries. However, due to specific conditions or to specific requirements, countries may of course decide to develop alternative or additional orthoimagery products, based on the wide range of available earth observation satellite images.

Satellite images are not always fit-for-purpose for surveying disasters. For instance, the disastrous event may have generated clouds or smokes (making the satellite images neither sharp nor reliable enough). And in some cases, even a short delay of 3 or 4 days before the satellite flies over the devastated area may still prove too long.

Good Practice 4
Member States would find it useful to set up relevant procedures, in order to be able, on short notices as required by disasters, to capture aerial images and to derive orthoimages.

4.3 Very fine resolution - Urban orthoimage (Master 0)

Fine-resolution orthoimages on urban areas are mainly required for two use cases:

- Use case 1: relative positioning of underground utility networks. A fine resolution orthoimage provides a detailed view of the streets, including pavement edges, road signs, road paintings, manholes, and thus offers valuable and geometrically reliable landmarks for relative georeferencing of utility network plans.
- Use case 2: a sub-product of a 3D model. The production of a 3D model generally requires the capture of fine resolution images. These being acquired,, their derivation into an orthoimage mosaic provides, at limited extra-costs, a valuable detailed 2D view of the city.

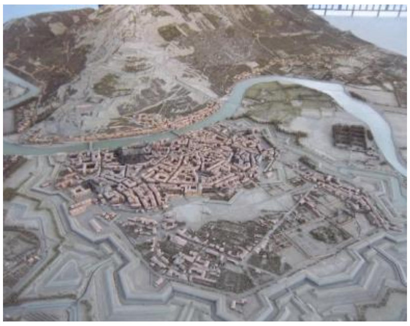


Figure 8: a 3D city model with orthoimages and 3D buildings wrapped on a DTM

Good Practice 5

When orthoimages are considered to be relevant for the relative georeferencing of utility networks, their characteristics should be close to the following ones:
- ground pixel size (spatial resolution, ground sampling distance): 10 cm or better, ideally 5 cm
- spectral resolution: Red Green Blue, each channel being encoded at least on 1 byte
- frequency: in principle, one shot product
- planimetric accuracy: better than 2 pixels
- source images: good visibility, large forward and side overlaps (70% or more) to minimise building tilt and thus occlusion of ground from buildings
- geographic extent: urban area

NOTE 1: Other methods may be used for georeferencing utility networks, such as stereo-plotting or mobile mapping or use of cadastral map for background data. However, the orthoimage is generally considered as more cost-effective.

NOTE 2: The main purpose of urban orthoimages is to display the whole extend of the streets. Source images should be collected when conditions match the application's requirements, ideally avoiding snow, bad weather, low sun angles but also vegetation. Hidden parts should be avoided. This is why large forward and side overlaps between images is required. In addition, legibility is enhanced if shadow effects are procedurally limited (e.g. by acquiring data where shadows are shortest) and/or automatically attenuated (e.g. through image-processing techniques).

NOTE 3: To ensure consistent accuracy, the ortho-rectification process should use relevant elevation data, typically a detailed DTM coming from Lidar or a DSM to produce a true orthoimage.

Good Practice 6

When orthoimages are considered as relevant complements to a detailed 3D model, their characteristics should be close to the following ones:
- ground pixel size (spatial resolution): 10 cm or better
- spectral resolution: Red Green Blue (and possibly near infrared), each channel being encoded at least on 1 byte
- frequency: that of the 3D model
- planimetric accuracy: better than 2 pixels
- source images: spring or summer flight (northern hemisphere), strong forward and lateral overlaps (70% or more) to minimise building tilt and thus occlusion of ground from buildings
- geographic extent: urban area

NOTE 1: images taken in spring or summer (northern hemisphere) show the vegetation, are more attractive for users, and are easier to capture and to process. Urban orthoimages may be used to manage public trees and green spaces; including the near infrared band would facilitate this type of use.

NOTE 3: the frequency recommended for 3D data on core theme Buildings is 3 years.

5 Other recommendations

5.1 Coordinate Reference System (CRS)

5.1.1 Case of 2D data

Good Practice 7 Core data should be stored and managed in a CRS based on datum ETRS89 in areas within its geographical scope, using either geographic or projected coordinates.

NOTE 1: Geographical scope of ETRS-89 excludes over-sea territories, such as Canary Islands or French Guyana or Madeira Islands and Azores Islands. In these cases, it is recommended to use a CRS based on ITRS (International Terrestrial Reference System).

NOTE 2: Storing and managing data in CRS based on international datum facilitates the import of measures from modern sensors, ensures that data is managed in a well-maintained geodetic framework and of course, facilitates the export of data into international CRS (e.g. those mandated by INSPIRE).

NOTE : If core data at regional and global levels has to be provided as a single data set on an area including over-sea territories, it is recommended to use as CRS geographic coordinates with any realisation of the International Terrestrial Reference System (ITRS), known as International Terrestrial Reference Frame (ITRF). At small or medium scales, all ITRS realisations can be considered as equivalent, as deviations between them are negligible compared to data accuracy.

Orthoimages are by nature 2D data.

5.2 Metadata

Good Practice 8 Core data should be documented by metadata for discovery and evaluation, as stated in the INSPIRE Technical Guidelines for metadata and for interoperability.

NOTE: This is an INSPIRE recommendation (only the INSPIRE Implementing Rules are legally binding for the Member States belonging to the European Union, but the Technical Guidelines are considered necessary to make the European Spatial Data Infrastructure work in practice). For the other countries, this is a way to make their data easily manageable by transnational users.

Core Recommendation 3
Core data on theme Orthoimage should be accompanied by a set of mosaic elements; the mosaic elements should be used to document the characteristics of the source image (mainly the date).

NOTE 1: Rationale for and concept of mosaicking elements are explained in the INSPIRE Data Specification.

5.2.1 Lineage

The characteristics of an orthoimage depend greatly of the source images used as source data. The potential image sources listed in the document "Core Spatial Data Theme Orthoimage - Recommendations for content" are recapitulated in the following table.

Orthoimage type	Status	Possible source image
Reference orthoimage (Master level 1)	Core recommendation	Digital airborne sensors (if affordable) Else satellite imagery
High frequency orthoimage (Master level 2)	Good practice	Satellite imagery
Very fine resolution orthoimage (Master level 0)	Good practice	Digital airborne sensors
Historical orthoimage	Good practice (delivery) Consideration for future (production)	Scanned film

NOTE 1: The image source is key information and should be documented in metadata, under the Lineage component.

NOTE 2: For very fine resolution orthoimages, use of images captured from drones may also be envisaged.

5.3 Delivery

It is expected that core data will be made available through improved existing products (or new products) or as INSPIRE data, and perhaps as specific core products (delivery issues still have to be investigated).

Core Recommendation 4
Core data should be made available under a few of the most current image formats including georeferencing.

NOTE 1: A good solution might be to provide orthoimage data both in a format without compression and in a format with compression. For instance, GeoTIFF may be used for non-compressed orthoimages whereas geo-enabled JPEG2000 and GMLJP2 may be used for compressed orthoimages. Geo-enabled JPEG2000 formats include GMLJP2 (that is an OGC standard) and GeoJP2 (that is a de facto standard). ECW may also be used as an effective format for display of orthoimage tiles and mosaics.

NOTE 2: Orthoimage data may be provided through physical support or through on-line services, such as Wep Map Services (WMS), WMTS (Web Map Tile Service) and Web Coverage Service (WCS), that is one of the download options recommended by INSPIRE. WMS with time parameter is relevant to be used enabling users to choose different time series. WMTS is a tile based WMS, proven to be effective in use of mosaics and services with different zoom layers displaying orthoimages with different resolutions.

Industrial production of orthoimages begun in the nineties (though orthoimages are existing since 1896 when Scheimpflug invented the first ortho-rectifier). Consequently, many data producers have several versions of historical orthoimage products. These products may be of great interest to study and understand the evolution of landscape over the last 20 years or so.

<u>Good Practice 9</u>
Data producers should make available for users the previous versions of their orthoimage products.

NOTE 1: Generally, the first versions of the orthoimages were not produced with such high standards as expected by the current practices and the recommendations of this document. However, they still provide quite valuable information.

6 Considerations for future

6.1 Production of historical orthoimages

Good practice 9 recommends the delivery of all the orthoimages that have been produced. This would provide significant benefit for limited effort.

In addition, many providers may have sets of aerial photographs that were taken before the ninety-nineties. Whereas many countries have already made historical versions of aerial photographs available by scanning and orthorectifying and serving data trough view and download web services, other countries have not produced orthoimage so far from these historical photographs or at least not in a systematic way.

The production of orthoimages from historical photographs is a topic to be considered for all holding such sources. Users in different sectors are interested to use time series to check for situations in previous years, or compare data in order to get information on changes over time, e.g. land use changes. Countries may have different strategies; some carry out systematic scanning of all photographs, some organise scanning only as on-demand production. Countries or holders of data may prioritise old photograph series, as these may be destroyed over time, e.g. data from the 30'ies. Others give priority to better quality and detailed photographs from 1950 onwards.

Some countries may have initiated such production. Sharing these experiences should be encouraged in order to gain better knowledge about potential methods and difficulties and about the costs-benefits to be expected.

6.2 Source images

Overlaps between two successive aerial images being greater than 50%, and side overlaps being what they are, there are at least two source images that may provide valuable information on any part of the extent of the aerial capture. Yet only one source is used for any pixel in the orthoimage. Users might be interested by the other source images, especially in the case of very fine spatial resolution orthoimages in urban area. For example, some images could show how the facades look like.

Research and experiment sharing should be encouraged in order to assess the interest of providing the whole set of source images and individual orthoimages to accompany the delivery of an orthoimage mosaic and to develop relevant tools enabling an easy use of this combination of various data.

7 Annex A: Relationship with INSPIRE Data model

7.1 Data Model

The UML models provided in this annex are only graphical illustrations of the core recommendations and of the good practices present in this document.

The recommendations for content are represented by highlighting the selected attributes in the following way:

Core recommendation

Good practice

The INSPIRE Data Specification propose a data model for theme Orthoimage, this model is based on the concept of coverage. The INSPIRE data model is (likely) very useful for ensuring efficient and interoperable delivery of data, especially through Web Coverage Services which is one of the download options for INSPIRE coverage data.

However, the coverage data model provides almost no information about the required content of orthoimages; this is why the UN-GGIM: Europe WG on core data is not proposing any data model for the orthoimage itself. The recommendations for content have been expressed in chapter 4 through defining the main characteristics, such as geometric resolution and accuracy, spectral resolution, frequency of production …

However, core recommendation 3, on the mosaicking graph, may be illustrated from the INSPIRE data model. The mosaicking graph should be delivered indeed in the form of a georeferenced vector dataset.

Core recommendation 3

Core data on theme Orthoimage should be accompanied by a set of mosaic elements; the mosaic elements should be used to document the characteristics of the source image (mainly the date).

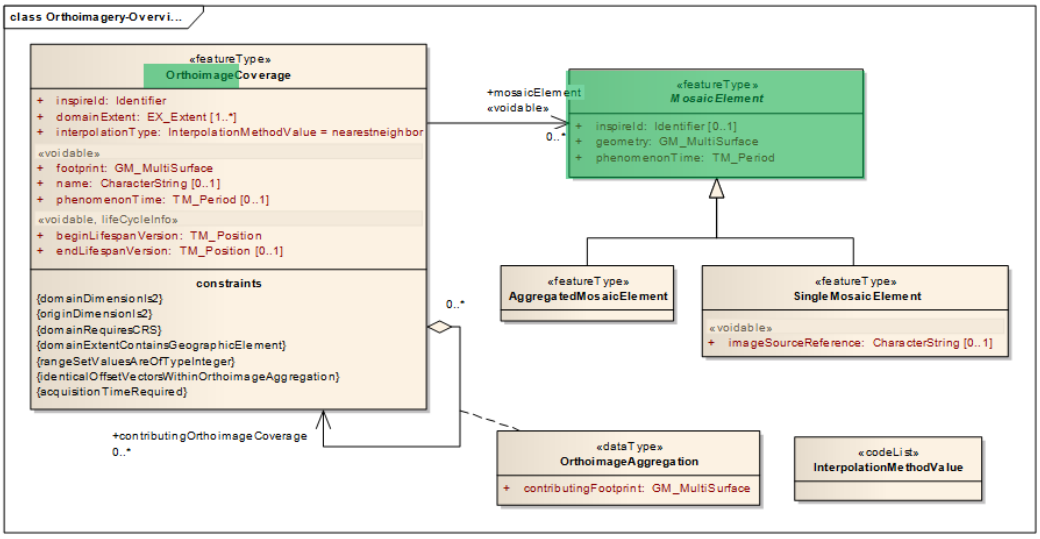


Figure 8: the vector mosaic elements document the date of source image.

7.2 Other topics

7.2.1 Scope

The scope of the present core data and of INSPIRE data are very similar as both are based on the same description. The INSPIRE exclusions also apply to core data. However, there are some differences, relating to the possible image sources.

INSPIRE lists as possible image sources:

- scanned film positives or negatives
- digital airborne sensors (such as frame cameras or push-broom sensors)
- satellite imagery of the Earth
- radar imaging systems
- LiDAR (Light Detection And Ranging) intensity images generated from point clouds.

As already mentioned in chapter 5.2.1, the potential image sources listed in the document "Core Spatial Data Theme Orthoimage - Recommendations for content" are recapitulated in the following table.

Orthoimage type	Status	Possible source image
Reference orthoimage (Master level 1)	Core recommendation	Digital airborne sensors (if affordable) Else satellite imagery
High frequency orthoimage (Master level 2)	Good practice	Satellite imagery
Very fine resolution orthoimage (Master level 0)	Good practice	Digital airborne sensors
Historical orthoimage	Good practice (delivery) Consideration for future (production)	Scanned film

As a consequence, the document "Core Spatial Data Theme Orthoimage - Recommendations for content" has only included the three first options among potential sources for INSPIRE (radar and LIDAR have not been considered as relevant because they are meant to be processed only by specific software used by experts). However, LIDAR data has been considered as relevant source data pour the production of the UN-GGIM: Europe spatial core data theme Elevation.

7.2.2 Data content

INSPIRE being based on existing data, the INSPIRE data specification doesn't include any requirement or even recommendation about the expected content of theme Orthoimagery. The data specification are only providing a well-documented data exchange "format" ensuring minimum interoperability by enabling users to easily understand INSPIRE data.

With a different perspective, the document “Core Spatial Data Theme Orthoimage - Recommendations for content” focuses on the main characteristics needed by the various families of orthoimages considered as necessary to fulfil main user requirements.

7.2.3 Data delivery

INSPIRE offers several options for default encoding of theme orthoimage, including TIFF and JPEG2000.

The document “Core Spatial Data Theme Orthoimage - Recommendations for content” considers that these two encodings are relevant in principle but under the condition that the georeferencing data is included in the format. This is why it is proposed to deliver orthoimages in GeoTIFF or in geo-enabled JPEG2000. Geo-enabled JPEG2000 formats include GMLJP2 (that is an OGC standard) and GeoJP2 (that is a de facto standard). Other formats, such as ECW, are also possible.

8 Annex B: Methodology

Core data specifications have been elaborated based on the one hand on user requirements (with focus on the ones related to SDG) and on the other hand on INSPIRE data specifications.

8.1 Understanding the issue: need for several products

In a first step, WG A identified the **general characteristics and the quality characteristics of an orthoimage.**

OI characteristics	OI Quality
• Geographic extent • Spectral resolution • Ground Sample Distance • Planimetric accuracy • Up-to-dateness • Coordinate Reference System • *"visibility"*	• Two criteria – Geometry & Visual aspect • Geometric quality : – accuracy – network continuity – buildings (rectified or not) • Radiometric quality – invisible edge matching – good global radiometric dynamic – visibility (% clouds, …)

After discussion, WG A agreed that:

- the main characteristics are the ground sample distance (spatial resolution), the spectral resolution and the up-to-dateness frequency (temporal resolution)
- an ideal orthoimage should have high spatial resolution, rich spectral resolution and high production frequency, what would be too costly to achieve
- therefore, **several products (or families) of product are necessary to cover a wide range of user requirements.**

8.2 Identifying the potential products

In a second step, WG A conducted an as-is analysis to identify the families of orthoimage products that are currently produced at European, national or local levels. From this analysis, it appeared that there are three main families of orthoimage:

- in urban areas, orthoimages at a very fine resolution (around 10 cm)
- at national level, orthoimages at a fine resolution (around 50 cm)
- at European level, orthoimages from satellite images, ensuring high frequency production process.

Among satellite images, those provided by the Copernicus Sentinel-2 program have been considered, without any doubt, as the most relevant ones, given their quick visit frequency (5 days), their rich spectral dynamic range, and their openness.

In addition to these main families, there may be other orthoimage products addressing more specific needs, such as orthoimage on coastal areas, historical orthoimages, night orthoimages, emergency orthoimages.

8.3 Defining priorities

The third and last step consisted in matching families of existing orthoimage products to user requirements in order to decide on the main priorities.

The user requirement investigation was based on the survey conducted during the first phase of WG A work (selection of core data themes) whose results are summarised in chapter 3.2 of this document (figure 1 and accompanying text). It was also completed by other bibliographic sources and when necessary, by interview of experts. For instance, WG A members wondered if it was worth to produce urban orthoimages and which were the use cases requiring such detailed (and costly) information.

The main existing product families have then be compared to the main roles of theme Orthoimage, as shown in following illustration and table.

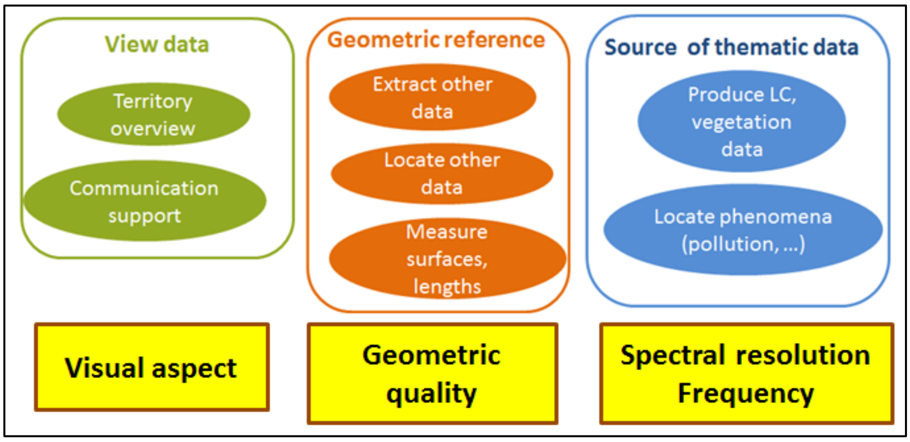


Figure 8: main use cases and related required characteristics

Family product	Role	Status	Comments
Reference orthoimage	**View data** **Geometric reference** Source of thematic data	Priority 1 Core recommendation	Source for thematic data: + near infrared band - low production frequency
High frequency orthoimage	**Source of thematic data** Geometric reference *View data*	Priority 2 Good practice	Geometric reference is limited to medium scale. *Satellite images more for machines than for human beings (view)*
Very fine resolution orthoimage	**Geometric reference** View data	Priority 2 Good practice	For specific use cases.

Regarding the specific additional products identified in the as-is analysis:

- orthoimage on coastal areas: it has been considered as a sub-case of the reference orthoimage (NOTE 3 of 4.1.1)
- historical orthoimage: they have been considered of interest; this is why it is advised to make accessible those that were already produced (good practice 9 in the Delivery chapter 5.3). In addition, it might be envisaged to produce orthoimages from old aerial photographs (considerations for future 6.1)
- night orthoimage: very limited use case (light pollution), not included in the document
- emergency orthoimage : though it is not a regular product, it has been considered of interest and advice is given to be being able to be able to produce it on demand (good practice 4).