BIO_SOS

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Abstract	The SDD describes the service chains as a function of expected products, available inputs and needed processing steps. It both describes the concrete service chains for the products defined by the SLAs and more abstract service chains for product categories together with a service implementation workflow that defines the base for the service implementation also for different sites.
Keywords	Service chain, workflow

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1. Executive summary

The EODHaM system will be an operational prototype of an ecological modelling system for effectively and multi-annual monitoring of NATURA 2000 sites (and other ecologically sensitive sites) and their surrounding areas.

The Service Design Document (SDD) is the summarizing deliverable product of task 3.1 (WP3) of the BIO_SOS project. The aim of task 3.1 is to outline the operational workflow of the EODHaM system by producing a workplan to be used in the architectural definition activities of the system and it's subsystems. This document is the first out of a series of technical reports that will support the design, the implementation and the demonstration/ utilization of the EODHaM system during activities of WP3 for implementation and WP7 for demonstration.

Important objective of this document is not only to present the service chain scenarios as these arise from the Service Level Agreement (SLA) signed between the BIO_SOS consortium and the managing authorities of the NATURA 2000 sites, but also to illustrate a generic service workflow that will be flexible and operational for any other ecologically sensitive area around the globe as well as to describe the actions and the workflow needed to get the system operational for these different sites .

2. Introduction

2.1 General Context

The main objective of BIO_SOS is the development of an operational ecological modelling system suitable for effective and timely multi-annual monitoring of NATURA 2000 sites and their surroundings in areas particularly exposed to different and combined types of pressure.

Due to several national and regional differences in policies/ funding and the lack of a centralised management of biodiversity data, even at the same regional-local level, a noticeable effort is required in order for a continuous, operational and quasi real-time monitoring of ecologically sensitive areas to be initiated. In search of such a monitoring system, the starting point should be to know the main 'actors' requirements and expectations. According to them, it is expected that such a system should:

- function at fine spatial scales (1:10,000 or finer) where habitats ought to be represented,
- be user-oriented efficient and reliable,
- be sensitive to changes in the input datasets and the user-defined parameters
- minimize the time between data acquisition and product delivery
- minimize the involved costs (e.g., by reducing manpower, exploiting open source software solutions, etc.)

Related to the aforementioned operational system requirements, BIO_SOS project will propose and develop the so-called EODHaM system, which intends to be an operational ecological modelling system for effectively and multi-annual monitoring of NATURA 2000 sites (and other ecologically sensitive areas) and their surrounding areas.

2.2 Purpose and scope of the document

At this stage the document describes the system's workflow chains as these are envisaged mainly through the SLA that was signed between the registered users and the BIO_SOS consortium and was already presented in a previous deliverable. A part of the document is dedicated to the description of the context in which the system will remain live and operational after BIO_SOS by setting some initial high level module requirements and putting down a general workflow composition idea which will be used to steer the subsequent module design and implementation from all related partners. Of course, the proposed system and its workflow are subject to further work and alterations during the life of the project.

2.3 A word on terms, assumptions and choices

2.3.1 Prior knowledge, ancillary data and meta-data

The DOW and other project related documents refer as input to several processing modules “prior knowledge”, “pre-existing data” and “ancillary data”. We assume that:

1. “prior knowledge” is information or rules that are incorporated into the system, thus they do not adapt to data and do not change with time. Prior knowledge is acquired by a supervisor or expert (human) based on intuition, expertise and evidence from data observation before (prior to) the data processing system starts looking at the remote sensing data available. In other words, prior knowledge is acquired by the supervisor and, next, taught by the supervisor to a deductive expert system (equivalent to a deductive machine teaching-by-rule paradigm) rather than being learned from data by an inductive information processing system (according to an inductive machine learning-from-data paradigm) . Thus “prior knowledge” is not part of any input data/information flows that we describe in this document.

2. "pre-existing data" and "ancillary data" are synonyms for data not directly derived from the main EO data input, but that may change from one processing to the other and thus must be considered in our workflow design. We use here the term "pre-existing data".
3. "Meta-data" is intended here as the set of parameters and fields that describe the content of Earth Observation or ancillary data in a "searchable" way. WP 4 and in particular D4.1 and D4.5, which are due to be delivered in the following months, will provide the guidelines for the meta-data collection, harmonization and availability to the system.

2.3.2 Partner responsibility referred to SW development

Whenever in this document, we indicate partners as responsible for a module, only the directly responsible partners for the development of the SW itself are cited (as kind of contact point for the system WP). This does not exclude that other partners will also contribute to such modules with their research or other activities.

2.3.3 Quality Assurance Framework for Earth Observation (QA4EO)

The international Quality Assurance Framework for Earth Observation (QA4EO), led by the Committee of Earth Observations (CEOS) Working Group on Calibration and Validation (WGCV) considers mandatory:

1. An appropriate coordinated program of calibration and validation (Cal/Val) activities throughout all stages of a spaceborne mission, from sensor building to end-of-life. This ensures the harmonization and interoperability of multi-sources observational data and derived products.
2. Metrological / statistically-based quality indicators (QIs), provided with a degree of uncertainty in measurements, to be established for all sensor derived data products.

2.3.4 Why we choose to accumulate meta-data throughout the processing chain

If you read on, you will find that the system accumulates and makes available to the following processing steps the references to all data sets used as inputs as well as to all results produced so far. This choice has the advantage of giving to any module the possibility to choose which input data that is present in the workflow until that point may be of interest and what can be produced with such data (this means, that in theory the result list of products that can be obtained by a module may differ in function of the available input data). Doing so, tears away the need for teaching the system the rules that are within the domain of the single module and for treating them all in the same way. This enables also a more flexible workflow design that can explore different combinations of modules (or even processing orders) in order to maximize the result.

3. EODHaM Service Definition

3.1 EODHaM in a nutshell

EODHaM is conceived to become potentially operational, i.e., effective, efficient, robust and scalable. Its input data sources are satellite-based measurements and ancillary data collected in-situ. Its seamless output products can support management decisions based on ecological status and trends according to National and EU obligations. EODHaM will be tested and validated in sampling sites particularly exposed to different and combined types of pressures in ecologically sensitive areas. It will be compliant to ongoing GEOSS, GMES and INSPIRE initiatives.

EODHaM will consist of:

- A Remote Sensing Image Understanding System (RS-IUS) based on a two-stage stratified hierarchical classification system architecture. The RS-IUS first stage (which can be thought as the EODHaM First Stage) consists of an application-independent operational automatic pixel-based near-real time Spectral Rule-based (i.e., spectral model-driven) decision-tree classifier (SRC) [1],[2]. The RS-IUS second stage (which can be thought as the EODHaM Second Stage) comprises of a battery of:
  - stratified land cover class-specific application-dependent context-sensitive (e.g., texture, morphological, geometric, spatial topological and non-topological) feature extractors.
  - stratified land cover class-specific application-dependent context-sensitive classification modules, e.g., semantic nets for land cover (LC) class detection where spatial relationships and/or time transition between (2-D) objects are modelled.
- Modules for ecological modelling (which can be thought as the EODHaM Third Stage) at: 1) habitat level for both habitat maps production from land cover and on-site data. Habitat maps will be obtained by interpreting regional land cover maps of sufficient detail with in-situ and ancillary data, other EO derived products and where appropriate, by merging similar land cover classes, according to the 92/43 EEC Directive and to General Habitat Categories (GHCs). 2) Landscape level for scenario analysis: 2a) context modelling will be considered to simulate landscape changes over different spatial and temporal scales and will be based on actual and envisaged land management strategies; 2b) site specific models will interpret the interaction that soil and vegetation under combined human pressures may have on biodiversity maintenance; 2c) species specific ecological modelling tools will be used to guide threat identification and impact quantification.
- Semantic-driven change detection modules, such as semantic nets capable of modelling time transitions between LC classes, to provide change maps i.e. LC Change (LCC) maps and Habitat Change (HC) maps, indicator trends and warning maps to Management authorities for indicating area were on-site intervention is required.

It is worth to mention, that all these different processing modules are supposed to follow some common standards and conventions in order to be able to combine them.

3.2 High level module requirements and general workflow composition idea

EODHaM will be a "system of systems" that employs various stages of processing to deliver various thematic maps for biodiversity monitoring and management. As such, it is foreseen that it will integrate different technologies and different levels of automation while trying to remain efficient and cost-worthy. At the same time the system must be designed in order to be operational and flexible, meaning that its modules and its services will not be site-specific. Achieving these targets can be a daunting task, that's why some high level module requirements must be respected and a general workflow composition idea should drive the development of all different modules and interfaces. This is crucial and should be considered during the system (workflow and modules) design and implementation.

3.2.1 Processing modules must be ready for integration in larger workflows

In particular, a processing module should respect four main high-level requirements (that will be refined in the architectural design of the system). It should:

- Be an independent executable, that does not required any human interaction
- Offer an "information function", that, given the metadata of a set of input files, will respond on which output will be produced (always as metadata).

  For example, an LC information extraction module should respond with a list of classes that this module is able to recognize with the given input files and the subset of the actual needed files from the input files in order to produce this output. This list could be empty. The set of potential input files may contain: "raw" EO data; previously elaborated data; other ancillary data that the workflow designer decided to give as inputs.

  Obviously some input data will be mandatory in order to make the module work (thus, each module should be accompanied with its specifications), but some may be optional or alternative. The parameters, that help a module to discriminate, which input files to include, may be for example (but not only): Sensor type; sensor resolution; region; extent, "type of information" etc.
- Retain an "as flexible as possible" approach in its design. For example, to avoid exact matches for the sensor type, but use a range of resolutions, type of data/bands and so forth, wherever possible.
- Offer a "processing" function, that given the input files returned as needed by the "information function" produces the envisaged output (if any).

Such an approach will allow for an "interactive workflow design", that means it enables the EODHaM system configurator, to explore unforeseen combinations of workflow steps in an easy way.

3.2.2 Processing modules should declare their expected "uncertainty"

"Uncertainty" may affect different types of parameters, like:

- numeric precision
- geometric precision
- reliability of extracted information
- …

Some of these uncertainties (for example numeric and geometric precision) can usually be expressed in fix ranges referred to the precision of the input data (min, avg and max error). Others may need subsequent manual validations in order to be evaluated, but the goal should be, that these validations have not to be executed for each processing, but only once in a while for an entire class of processing in order to become part of the ancillary data (or metadata) in input to the processing. The service and workflow design then shall not identify the single quality parameters intrinsic to the processing modules, but provide the means to be able to collect and propagate such information throughout the processing chain. This propagation should start from the metadata definition of the input data and add for each processing step the predefined precision ranges of each processing module for each identified parameter. During architecture design, the feasibility of standards such as UncertML [11] will be studied in order to fulfill this requirement.

It is up to the single processing modules, to identify the parameters that are subject to suffer from the processing and then to evaluate the relative error ranges in order to express the uncertainty.

It is worth to mention, that by now these errors/ranges are intended to be fix for a module and not dependent on the input data's content but dependent on the declared precision of the input data (thus the input data's metadata), that may vary also in function of the position within the overall workflow.

This means, that besides the aforesaid “information” and “processing” functions, a module should expose also an “uncertainty update” function, in order to update the uncertainty propagation. If an algorithm is able to express better these ranges in function of the actual content of the input data, such an approach should be studied by the algorithm designers and its “after-processing” results should be used for error propagation (as the results would be expected to be better, especially for the max. error). Therefore, this function will most probably called after the processing, in order to give the module a chance to do such evaluations where possible.

4. Current Service Chain constraints

The service chain is the technological implementation of the pre-defined methodology describing the relation between the elements (building blocks) of the EODHaM system, that will provide, as a result, geospatial information in support of habitat monitoring. The building blocks (subsystems or modules) of the EODHaM system and the relations that grow between them, complete a series of service chain scenarios that will be used to produce the core services of the project. The service chain scenarios are primarily driven from the users and their site-specific requirements and emerging constraints (agreed and presented in the Service Level Agreement document) but also from the Quality Assurance Plan (QAP) that was planned between the partners of the consortium.

The constraints that arise from the QAP are mostly related to data and are used to standardize the inputs and outputs of the EODHaM system. The constraints that derive from the SLA are presented in the following chapters.

4.1 SLA Product List

The SLA, presented in deliverable D2.3, is the formal expression of the result of the negotiation between user needs and service provider capabilities. In this way, it defines the respective commitments between a service provider (BIO_SOS consortium) and a service user (reference users are presented in table 1) and therefore the main service chain scenarios, the inputs, the intermediate workflow steps and the outputs of the EODHaM system.

Following the signed SLA between the consortium and the users, the main outputs of the system will consist of the following maps:

- Land cover maps (FAO-LCCS)
- Land cover change maps
- Habitat maps (GHC and Annex 1 Habitat maps)
- Habitat change maps
- Specific land cover class transitions maps
- Biodiversity indicators maps

The spatial resolution of the maps will range from high to very high resolution. This will provide:

- updated full coverage of the corresponding sites
- fine scale mapping of areas exposed to specific pressure (e.g. boundary areas);
- early warning of areas where on-site inspection is required.

Table 1, summarizes the products that the EODHaM system will produce for the study sites.

Table 1: Summary of the products that will be delivered to each user, according to the signed SLA.

Country	Reference User	Products to be delivered
Italy	Regione Puglia, Servizio Ecologia - Ufficio Parchi	Land Cover/ Land Cover Change map/ Habitat map/ Habitat Change map/ Land Cover Transition map/ Biodiveristy indicators
Greece	Management institution of Kalamas - kalodiki	Land Cover/ Land Cover Change map/ Habitat map/ Habitat Change map/ Land Cover Transition map/ Biodiveristy indicators
Netherlands	Ministry of Defense for the heathland area Ginkelse and Ederheide, and Geldersch Landschap for the inland sand dune area of Wekeromse Zand	Not yet available
Portugal	Instituto da Conservação da Natureza e da Biodiversidade (ICNB)	Land Cover/ Land Cover Change map/ Habitat map/ Habitat Change map/ Land Cover Transition map/ Biodiveristy indicators
UK	Countryside Council for Wales	Land Cover/ Land Cover Change map/ Habitat map/ Habitat Change map/ Land Cover Transition map/ Biodiveristy indicators
Brazil	Instituto National De Pesquisa Espaciais (INPE)	Land Cover map of human-modified areas, Primary forest/ human-modified mask

5. Operational Scenarios

A scenario is a step-by-step description of how the proposed system should operate and interact with its users and its external interfaces under a given set of circumstances. The scenarios tie together all parts of the system, the users, and other entities by describing how they interact.

5.1 EODHaM operational elements

From an operational point of view, the following operational elements (figure 1) can be individuated in the EODHaM system:

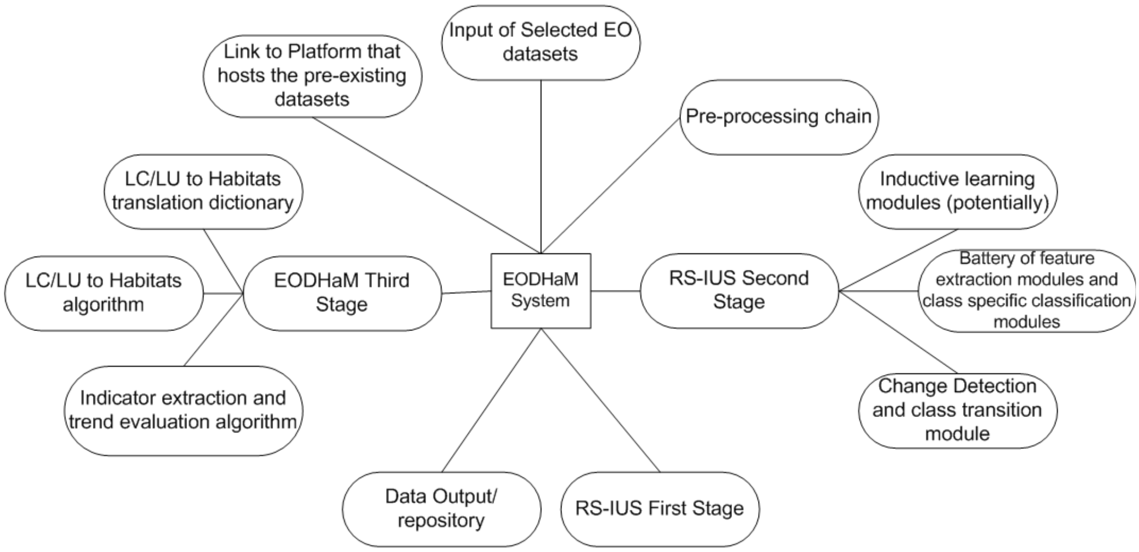


Figure 1: EODHaM's system elements

- **Data Input**: it's the entry point to the System which will be hosted by a user-friendly interface. EO Data are expected to be radiometrically calibrated and geometrically corrected before they enter the processing chain and feed the first processing module (RS-IUS first stage). The suitability of data depends on their spatial, spectral and temporal resolution characteristics in respect with the different habitats types, ecological scales of fragmentation and human scales of impact on each site. Partner 5 (ATREE) is responsible for the definition of the criteria for EO data selection, whilst partner 13 (PKH) for the design and implementation of the data input interface (task 3.4).

- **Link to a Collaborative platform that will host metadata for all pre-existing datasets**: Pre-existing datasets are essential for the successful implementation and delivery of the products from the system. A dedicated collaborative platform will be developed to host the metadata of these datasets. It is expected, that the system will be able to communicate with this platform and get links for the data that are needed to feed particular steps within its processing chains. These datasets may include: in-situ ecological datasets resulting from previous field surveys, other ancillary data such as pan-european spatial databases (e.g. GLC2000, LC/LU CLC, PELCOM), national and regional relevant databases, statistical data associated to population, economic activities, regional and local master plans and Natura 2000 management plans. All datasets will be organised according to the Annexes and Data Specifications of the INSPIRE Directive. The description of the spatial database by metadata profiles (ISO 19115 and 19139) will support a spatial, thematic, temporal completeness and logical

consistency quality analysis (ISO 19113, 19114 and 19118) to enable geographic data to be shared and widely available in across application domains. Partner 9 (CIBIO) is responsible for collecting the pre-existing data and metadata from the various partners and implementing the platform (task 4.1), while Partners 1, 2, 8, 12, 4, 11 are responsible for providing data and metadata according to the different test sites.

- **Pre-processing chain:** At the base of the three EO data processing stages of EODHaM is the pre-processing chain. The processing steps include:

  1. A mandatory radiometric calibration of Digital Numbers (DN) into physical values belonging to a community-agreed radiometric scale, namely, top-of-atmosphere-reflectance (TOARF). This radiometric calibration requirement is in agreement with the GEO-CEOS Quality Assurance Framework for EO (QA4EO).
  2. An opional atmospheric correction of an MS image radiometrically calibrated into TOARF values, to be transformed into surface reflectance (SURF) values. It is noteworthy that SURF values are a special case of TOARF values when atmospheric effects are negligible.
  3. the geometric correction/ geometric projection/ orthorectification of the radiometrically calibrated image. A DEM and a set of Ground Control Points (GCPs) are mandatory for orthorectification.
  4. Panchromatic sharpening of the orthorectified MS image radiometrically calibrated into TOARF or SURF, if possible (e.g., a higher-resolution panchromatic image is available together with the lower-resolution MS image) and required.
  5. Finally, the stratified topographic correction of the orthorectified radiometrically calibrated MS image. A Digital Elevation Model (DEM), the sun zenith and azimuth angles are mandatory for orthorectification, together with a SIAM preliminary classification map for stratification;The output of the pre-processing chain is a topographically corrected orthorectified MS image radiometrically calibrated into TOARF or SURF values. This topographically corrected MS image is input to the RS-IUS First stage module.

  Partner 15 (BACRES) is responsible for delivering the pre-processing module to the system. The following diagram (figure 2) illustrates the pre-processing workflow chain.

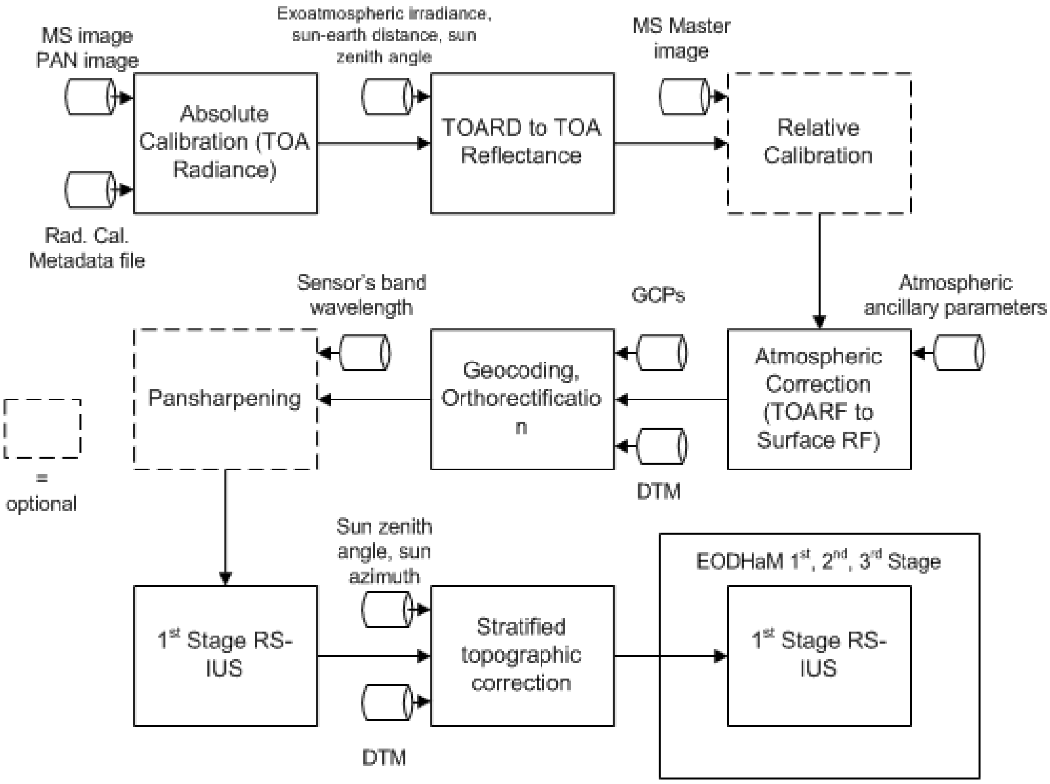


Figure 2: EODHaM's pre-processing chain

- **RS – IUS First Stage (EODHaM 1st Stage)**: RS-IUS first stage is the first stage of processing of the pre-processed input data within EODHaM. Inputs of this module are topographically corrected orthorectified (preferably pan-sharpened) MS images radiometrically calibrated into TOARF or SURF values and pre-existing datasets and its outputs are:
  1. Categorical variables belonging to a discrete and finite set of semantic labels. These semantic labels are called spectral-based semi-concepts, color-based image layers (strata), spectral categories or land cover class sets. Spectral categories are mutually exclusive and totally exhaustive. Examples are: *vegetation*, *cloud*, *bare soil or built-up*, *water or shadow*, *snow or ice*, etc.
  2. Segmentation maps. Three-scale segmentation maps are generated from a well-posed segmentation problem of the three preliminary classification maps featuring fine, intermediate and coarse granularity respectively.
  3. Continuous variables, namely, spectral indexes, which can be related to bio-physical parameters (e.g., leaf area index, LAI).

  Partner 15 (BACRES) is responsible for providing and further improving this module (task 5.1).

- **RS – IUS Second Stage (EODHaM 2nd Stage):** The second stage of the RS-IUS leads to a LC/LU classification (e.g., broad-leaf forest, needle-leaf forest, etc). The 2nd-stage consists of a battery of stratified class- and application-specific feature extractors and classification modules. Inputs of this module are:
  1. MS image, if required.
  2. Brightness (panchromatic) image generated from the first stage from the input MS image.
  3. First stage preliminary classification map(s).

4. First stage segmentation map(s).
5. Spectral indexes generated by the first stage from the input MS image.

The output of the second stage is LC maps provided with a RS community-agreed legend (e.g., FAO-LCCS) which changes with the spatial and spectral resolution of the input MS image. The RS-IUS second stage classification is based on the use of any further information that can be extracted from the images that are being processed. Such information can be derived from: stratified context-sensitive feature extraction modules; segment-based geometric attributes (e.g. area, perimeter, compactness, straightness of boundaries, elongation, rectangularity, number of vertices, etc); stratified multi-scale morphological attributes (e.g. differential morphological profile); spatial non-topological relationships between segments (e.g. distance, angle/ orientation, etc); spatial topological relationships between segments (e.g. adjacency, inclusion, etc). Using this information, the RS-IUS second stage performs a second class-specific fuzzy rule-based classification and delivers as outputs LC/LU maps. Partner 12 (IRD) together with partner 1 (CNR) and 15 (BACRES) are responsible for the collection or implementation of the various modules that will construct the second stage RS-IUS (task 5.2).

- **Inductive learning modules for the second stage RS-IUS classifier (potentially)**: Inductive (data-driven) learning modules for data segmentation and classification were included in the initial project proposal and might be added to the EODHaM Second Stage reducing, in this way, the risk of failure in providing LC/LU maps to the users. Partner 1 is responsible for further developing and providing these modules to be used in the system (task 5.3) if needed. However, the main research work will focus on the development of deductive learning modules.

- **Change detection and class transitions extraction module**: These module includes semantic-based change detection techniques developed and by partner 1 (CNR) and partner 15. Ground truth data, provided by WP4, will help in improving and validating these techniques in order to be used in EODHaM. The availability of a historical time-series of HR and VHR images and some no-change ground-truth can allow the detection of LU/LC changes and the trend of each LC/LU class in time. The information derived by change matrices, evaluated on the base of pixel class label frequency, will provide specific probability class-transitions and then the trend of each class. Partners 1 (CNR) and 15 (BACRES) are responsible for improving and delivering this module (task 5.4).

- **EODHaM Third Stage:** Within the Third Stage of EODHaM, GHC detection and GHC change detection is performed. For the GHC detection inputs are:

  1. LC maps.
  2. LCC maps.
  3. First stage preliminary classification maps.
  4. Spectral indexes generated from the first stage from the MS image.
  5. Other ancillary information sources,

  while outputs are:

  1. GHC maps provided with a legend which changes with the special and spectral resolution of the input MS image.
  2. Habitat maps provided with a legend which changes with the spatial and spectral resolution of the input MS image.

For the GHC change detection inputs are GHC maps through time while outputs are GHC change maps provided with a legend which depends on the spatial and spectral resolution of the input MS image.

- **Modelling at habitat level (Design of the LC/LU to GHC and Annex 1 Habitat algorithm)**: Translating LC/LU classes in onto GHCs and Annex 1 Habitat maps implies many-to-many relationships. Within this module, the relationships between LC/LU classes and Habitat maps will be identified after the identification of the LC/LU taxonomy the most suitable for this mapping. This will lead to a "dictionary" for translating LC/LU into habitat maps and the algorithm for the conversion itself. Achieving a correct correlation of LC/LU categories and corresponding Habitats isn't always a straightforward task. Furthermore, some LC categories do not fall to any Habitat category described in the Directive 92/43 EEC. Due to this, a translation "dictionary" will be implemented in order to standardize the conversion of LC/LU maps into Habitat maps. Partners 3 (CERTH) and 1 (CNR) are responsible of this task (task 6.1) and will deliver the corresponding module.

- **Modelling at Habitat level (Implementation of the LC/LU to GHC and Annex 1 Habitat algorithm)**: This algorithm will be implemented and incorporated to the system for the conversion of LC/LU maps into GHCs and Annex I Habitat maps as well as into Habitat not included in Annex 1 of the Directive but of great ecological value in the Mediterranean sites will also be considered (task 6.1). The reliability of each measurement as an indicator of habitat type and the reliability of the process by which it was estimated will be taken into consideration, in order to work out the classification of the type of habitat. The refinement of the proposed algorithm within EODHaM 3rd stage will be a constant procedure to concur with parallel activities in BIO_SOS throughout the duration of the project. In particular, to increase the classification accuracy of GHCs generated from LCCS classes, the initial many-to-many relationships of LCCS classes onto GHCs will be better constrained (modelled) to obtain ideal one-to-one relationships or at least one-to-few relationships. To better condition the EODHaM 3rd-stage mapping of LCCS classes into GHCs, two strategies will be pursued in parallel.
  - Employ as input additional sources of ancillary information (where ancillary information is defined as non-pictorial information which cannot be detected in RS imagery), if any.
  - Adopt semantic nets, consisting of nodes, equivalent to classes of objects, and arcs (relationships) between nodes. Possible relationships between LCCS classes and GHCs are expected to be the following.
    - PART-OF.
    - KIND-OF.
    - Topological, e.g., inclusion, adjacency.
    - Non-topological, e.g., distance, angle.
    - Time transitions.

  It is noteworthy that semantic nets are also adopted by the EODHaM 2nd stage to generate as output LCCS classes from input spectral categories automatically detected by the 1st-stage SIAM™ preliminary classifier. This means that a synergistic use of semantic nets is expected by both the EODHaM 2nd and 3rd stages. Partners 1 (CNR) and 3 (CERTH) are responsible for the design and implementation of this algorithm (task 6.6).

- **Modelling at Landscape level (Algorithm for indicator production and their trend evaluation)**: This module will be based on an expert system that combines observation data (fed by other tasks of the project) in order to implement an algorithm for indicator extraction and trend evaluation. Rules and correlations will be used in order to extrapolate current observations in time. The indicators and state,

as well as the historical information concerning the site will be used by the developed inference engine (semantic nets) to work out the predicted change in habitat in a particular area. A warning signal will be extracted and provided in a map form. Partner 3 (CERTH), together with 1 (CNR) and 5 (ATREE), is responsible for developing and delivering this algorithm (task 6.7).

- **Data Output/repository**: it's the exit point of the System which will enable the instant delivery of the products and their metadata in popular format to the user, but also the storage of the processed data in a collaborative database for further actions of the project's partners. Partner 13 (PKH) is responsible for the design and implementation of the data output interface (task 3.4).

Table 2 summarizes the operational elements that can be individuated in the EODHaM system and the partners within the consortium that are responsible for their design and implementation.

Table 2: EODHaM's known elements and the partners that are responsible for their design and implementation.

Element	Task	Responsible partners
Data input module	3,4	PKH
Collaborative platform for pre-existing datasets	4,1	CIBIO
Pre-processing chain		BACRES
RS-IUS First Stage (EODHaM 1st Stage)	5,1	BACRES
RS-IUS Second Stage (EODHaM 2nd Stage) - Battery of feature extraction modules and class specific classification modules	5,2	IRD, CNR, BACRES
Inductive learning modules for the 2nd Stage of EODHaM (potentially)	5,3	CNR
Change Detection and class transition module	5,4	CNR, BACRES
LC/LU to GHC and Annex 1 Habitat mapping: Design of the algorithm	6,1	CERTH, CNR
LC/LU to GHC and Annex1 habitat maps: algorithm implementation	6,6	CNR, CERTH
Indicator extraction and trend evaluation algorithm	6,7	CERTH, ATREE, CNR
Data output module	3,4	PKH

5.2 Operational scenarios and product chain definitions

This section provides the service chains for every product that will be delivered from the project to the users.

5.2.1 Land cover/ Land Use maps

Product Description: Land Cover/ Land Use maps will be produced for all the study sites. These maps can be thought as the base products which will be used as inputs for the production of other second level products (e.g. Habitat maps). In deliverable D6.1, it was suggested that a Land Cover Categorisation System [6], [7] should be adopted in order to allow for a successful transition between LC classes and Habitats. Thus, the FAO-LCCS is selected as the BIO_SOS multilevel LC taxonomy (inventory), which is both hierarchical and well posed and it has proven to be a valid tool in the detection of LC changes that will also have to be reported in maps. The LCCS aims at capturing any land cover all over the world, independently of specific applications and/or geographical areas. It is intended to overcome problems due to the interpretation of different land cover class definitions, because, rather than establishing other land cover classes based on nomenclature, it defines a set of independent diagnostic criteria strictly based on vegetation physiognomy and structure, leading to criteria-based land cover classes, compatible with any definition, and allowing for relation with existing classifications and labels [7].

Workflow Description: LC/LU maps will be obtained as final outputs in a processing chain consisting of the following elements:

- Data Input
- Link to collaborative platform
- RS-IUS First Stage (EODHaM 1st Stage)
- RS-IUS Second Stage (EODHaM 2nd Stage)
- Data Output/ Repository

The following diagram (figure 3) illustrates the product's workflow within the system, while table 3 summarizes the known, the involved processing steps and the information exchange between them.

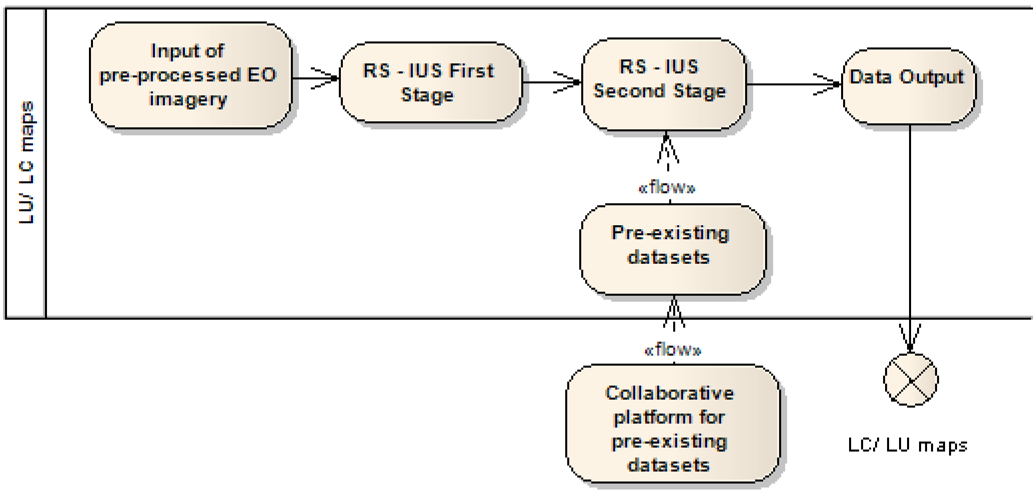


Figure 3: Workflow chain for the production of LC/LU maps.

Table 3: The involved processing steps for the delivery of LC/LU maps and the information exchange between them.

Known elements within EODHaM	Input information	Output information	Information exchange	constraints/ dependencies/ other information	Related Partners **(prime)**
Data Input	Pre-processed HR to VHR imagery		Selected Imagery to the RS-IUS First Stage	Orthorectified imagery (TOARF values)	PKH
Link to pre-existing datasets		Pre-existing data for the areas of study	Pre-existing data and metadata as inputs to the EODHaM 2nd Stage	Link to the collaborative platform that hosts the data and their metadata	CIBIO
RS-IUS First Stage	Pre-processed imagery	Preliminary classification map, spectral indices	Pre-processed data through the first stage of the RS-IUS	Fully automatic procedure	BACRES
RS-IUS Second Stage	Preliminary classification map, spectral indices	LC/ LU maps	Preliminary classified map and ancillary data through the Second Stage of EODHaM		**IRD**, CNR, BACRES
Data Output		**LC/LU maps**			

5.2.2 LC/LU Change maps

Product Description: Land use/ Land cover change maps will be produced for all study sites. There are two different ways that a change occurs within a classification scheme. Firstly, as a transition from a land cover class to another and secondly, as a modification within the same class. Transition implies an evident change which can be easily represented on a map , whereas modifications are less apparent and their representation in a map is not always possible, depending on the detail and flexibility of the LC classification used. With the LCCS approach, land cover change detection becomes possible both at the level of transition of a class, and modification within a certain class type. In this last case, the change becomes immediately identifiable by a difference in the output of a classifier, or through the use of additional qualifiers, although maintaining the same major class type [8],[9].

Workflow Description: LC/LU Change maps will be obtained as final outputs in a processing chain consisting of the following elements:

- Data Input
- Link to collaborative platform
- RS-IUS First Stage (EODHaM 1st Stage)
- RS-IUS Second Stage (EODHaM 2nd Stage)
- Change Detection and class transition module
- Data Output/ Repository

The following diagram (figure 4) illustrates the product's workflow within the system, while table 4 summarizes the known, involved processing steps and the information exchange between them.

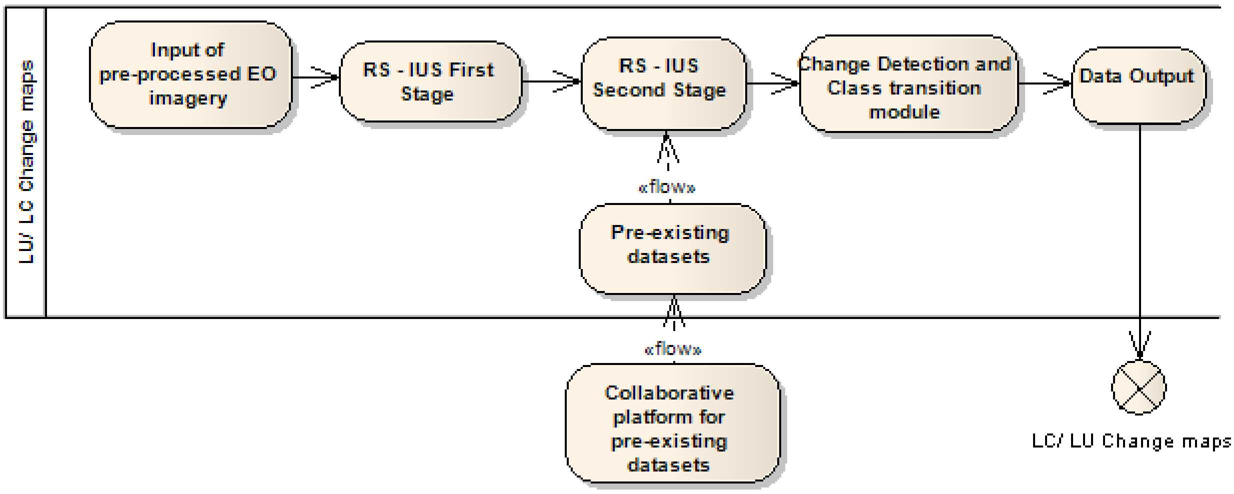


Figure 4: Workflow chain for the production of LC/ LU change maps.

Table 4: The involved processing steps for the delivery of LC/LU Change maps and the information exchange between them.

Known elements within EODHaM	Input information	Output information	Information exchange	constraints/ dependencies/ other information	Related Partners **(prime)**
Data Input	Pre-processed HR to VHR imagery		Selected Imagery to the RS-IUS First Stage	Orthorectified imagery (TOARF values)	PKH
Link to pre-existing datasets		Pre-existing data for the areas of study	Pre-existing data and metadata as inputs to the EODHaM 2nd Stage	Link to the collaborative platform that hosts the data and their metadata	CIBIO
RS-IUS First Stage	Pre-processed imagery	Preliminary classification map, spectral indices	Pre-processed data through the first stage of the RS-IUS	Fully automatic procedure	BACRES
RS-IUS Second Stage	Preliminary classification map, spectral indices,pre-existing datasets	LC/ LU maps	Preliminary classified map and ancillary data through the Second Stage of EODHaM		**IRD**, CNR, BACRES
Change detection and class transition module	Multitemporal LC/LU maps, pre-existing datasets	LC/ LU Change maps	Multitemporal LC/ LU maps through the change detection and class transition module		**CNR**, BACRES
Data Output		**LC/LU Change maps**			

5.2.3 Habitat maps

Product description:

The monitoring of distribution and status of relevant target ecosystems in Natura 2000 sites and their surrounding will be based on the production of updated habitat maps, as these appear to be at the base of the many biodiversity indicators [10]. As recognized in the EBONE Handbook [3], habitats can be considered as an ecological refinement of the LCCS categorisation as developed by FAO [4]. The output habitat maps will be under the GHC framework and/or the Annex 1 of the European Directive, which are also related to each other. The transition of GHC codes to Annex I codes has been fully described in the EBONE Handbook [5]. A rule based key to Annex I habitats has been produced using GHCs to provide a hierarchical key. The Key is available as EBONE Deliverable 4.2 through "www.ebone.wur.nl". As evidenced in D6.10, in the Mediterranean Natura sites selected for BIO_SOS, several habitat types, which are of great ecological importance, are not considered by Annex I of the EU Directive [see D6.1], even if functionally linked to habitats included in Annex I. For IT4 and IT3 sites, such habitats are listed in Table IT4_1 and IT3_1 of D6.1 and evidenced by an X code in the Annex I column. For this reason, within BIO_SOS, focusing mainly on Mediterranean Natura 2000 sites, a specific set of expert rules will be defined for the direct mapping of LCCS classes to both GHC and habitat types as expressed by other habitats classification taxonomy, such as CORINE Biotopes or EUNIS to satisfy user requirements.

For any reference to both Annex I of the EU Habitats and Species Directive, as well as other Habitat classification taxonomies see D6.1.

Workflow Description: Habitat maps will be produced for all study sites. Habitat maps will be obtained as final outputs in a processing chain consisting of the following elements:

- Data Input
- Link to collaborative platform
- RS-IUS First Stage (EODHaM 1st Stage)
- RS-IUS Second Stage (EODHaM 2nd Stage)
- EODHaM 3rd Stage
  - LC/LU to GHC and Annex 1 (and other habitat taxonomies for habitats not included in Annex 1 but existing in the Mediterranean sites considered in BIO_SOS) Habitat maps algorithm
- Data Output/ Repository

The following diagram (figure 5) illustrates the product's workflow within the system, while table 5 summarizes the known, involved processing steps and the information exchange between them.

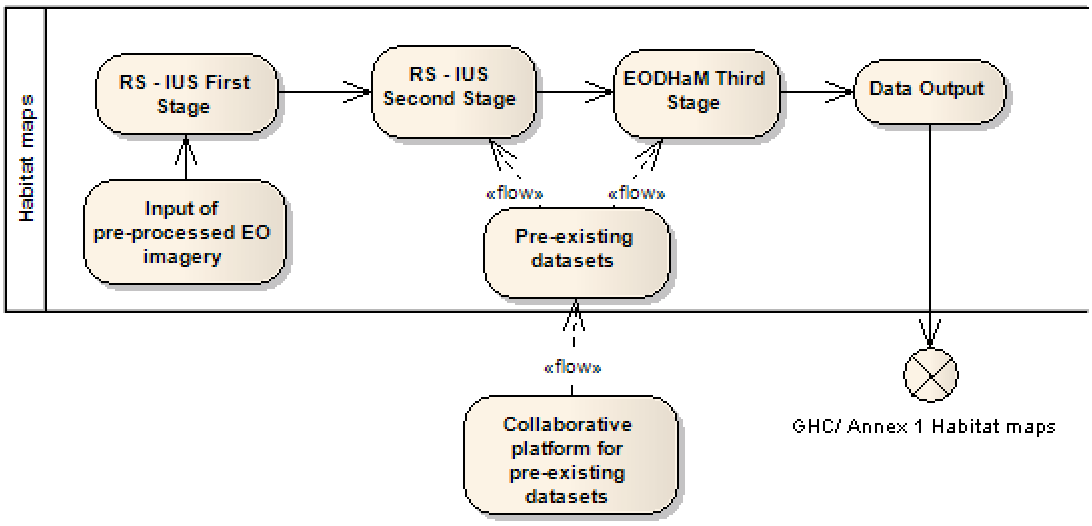


Figure 5: Workflow chain for the production of GHC/ Annex 1 Habitat maps.

Table 5: The involved processing steps for the delivery of Habitat maps and the information exchange between them.

Known elements within EODHaM	Input information	Output information	Information exchange	constraints/ dependencies/ other information	Related Partners **(prime)**
Data Input	Pre-processed HR to VHR imagery		Selected Imagery to the RS-IUS First Stage	Orthorectified imagery (TOARF values)	PKH
Link to pre-existing datasets		Pre-existing data for the areas of study	Pre-existing data and metadata as inputs to the EODHaM 2nd and 3rd Stages	Link to the collaborative platform that hosts the data and their metadata	CIBIO
RS-IUS First Stage	Pre-processed imagery	Preliminary classification map, spectral indices	Pre-processed data through the first stage of the RS-IUS	Fully automatic procedure	BACRES
RS-IUS Second Stage	Preliminary classification map, spectral indices, pre-existing datasets	LC/ LU maps	Preliminary classified map and ancillary data through the Second Stage of EODHaM		**IRD**, CNR, BACRES
LC/LU to GHC and Annex1 habitat maps algorithm	LC/ LU maps, Preliminary Classification map, spectral indices, pre-existing datasets	GHC and Annex 1 Habitat maps	LC/ LU maps and ancillary data through the conversion algorithm of EODHaM's Third Stage		**CNR**, CERTH
Data Output		**GHC and Annex 1 Habitat Maps**			

5.2.4 Habitat Change maps

Product Description: The GHC scheme is specifically designed to record in a consistent way, same areas at different dates for detection and mapping of changes. In addition, this scheme forces stringent criteria to ensure that real changes within the habitats are recorded and that the results are not distorted by differences in definitions, between observers or in recording techniques. One of the key elements of this approach is its potential for the detection and evaluation of flows between habitats [4]. Like the FAO LC Classification system, the GHC classification system is a promising tool for the detection of changes, not only those involving a change from a habitat type to another, but also those involving a modification within the same habitat type.

Workflow Description: Habitat change maps will be produced for all study sites. Habitat change maps will be obtained as final outputs in a processing chain consisting of the following elements:

- Data Input
- Link to collaborative platform
- RS-IUS First Stage (EODHaM 1st Stage)
- RS-IUS Second Stage (EODHaM 2nd Stage)
- EODHaM 3rd Stage
  - LC/LU to GHC and Annex 1 (and other habitat taxonomies for habitats not included in Annex 1 but existing in the Mediterranean sites considered in BIO_SOS) Habitat maps algorithm
- Change Detection and class transition module
- Data Output/ Repository

The following diagram (figure 6) illustrates the product's workflow within the system, while table 6 summarizes the known, involved processing steps and the information exchange between them.

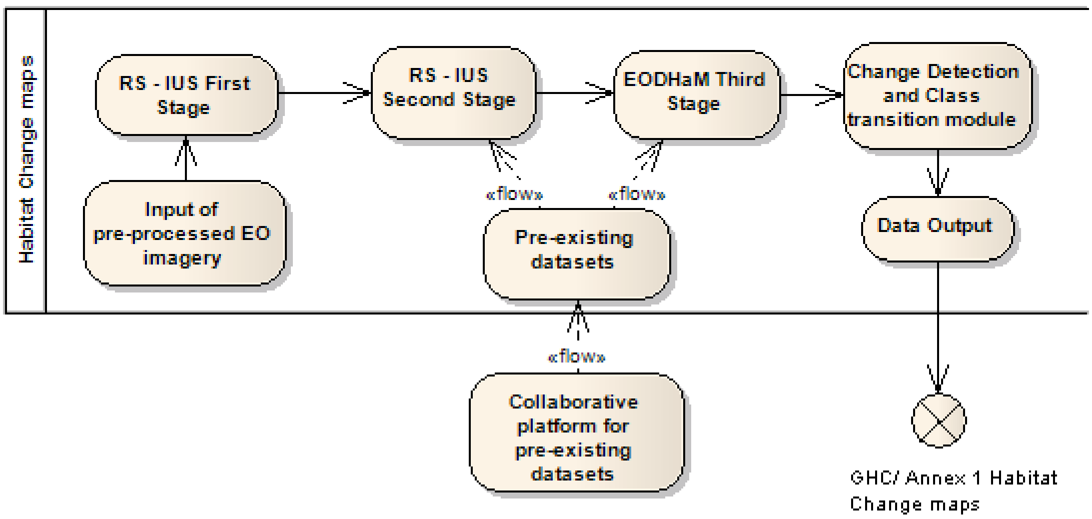


Figure 6: Workflow chain for the production of GHC/ Annex 1 Habitat Change maps.

Table 6: The involved processing steps for the delivery of Habitat Change maps and the information exchange between them.

Known elements within EODHaM	Input information	Output information	Information exchange	constraints/ dependencies/ other information	Related Partners **(prime)**
Data Input	Pre-processed HR to VHR imagery		Selected Imagery to the RS-IUS First Stage	Orthorectified imagery (TOARF values)	PKH
Link to pre-existing datasets		Pre-existing data for the areas of study	Pre-existing data and metadata as inputs to the EODHaM 2nd and 3rd Stages	Link to the collaborative platform that hosts the data and their metadata	CIBIO
RS-IUS First Stage	Mutlitemporal Pre-processed imagery	Preliminary classification maps, spectral indices	Pre-processed data through the first stage of the RS-IUS	Fully automatic procedure	BACRES
RS-IUS Second Stage	Preliminary classification maps, spectral indices, pre-existing datasets	Multitemporal LC/ LU maps	Preliminary classified maps and ancillary data through the Second Stage of EODHaM		**IRD**,CNR, BACRES
LC/LU to GHC and Annex1 habitat maps algorithm	Multitemporal LC/ LU maps,Preliminary Classification maps, spectral indices, pre-existing datasets	Multitemporal GHC and Annex 1 Habitat maps	LC/ LU maps and ancillary data through the conversion algorithm of EODHaM's Third Stage		**CNR**, CERTH
Change detection and class transition module	Multitemporal GHC and Annex 1 Habitat maps	Habitat Change maps	Multitemporal Habitat maps through the change detection and class transition module		**CNR**, BACRES
Data Output		**GHC and Annex 1 Habitat Change Maps**			

5.2.5 Land Cover Class transitions

Product Description: LC/LU Class Transition maps will be produced for all study sites. As mentioned before, a transition implies an evident change which can be easily represented on a map. Aim of these separate products is to record specific LC/LU transitions as these are requested from EODHaM users. For each study site, the LC/LU class transitions of interest can be extracted by considering the list of pressures affecting the habitats. These pressures are reported and described in D2.2.

Workflow Description: The LC/LU class transition maps will be obtained as final outputs in a processing chain consisting of the following elements:

- Data Input
- Link to collaborative platform
- RS-IUS First Stage (EODHaM 1st Stage)

- RS-IUS Second Stage (EODHaM 2nd Stage)
- Change Detection and class transition module
- Data Output/ Repository

The following diagram (figure 7) illustrates the product's workflow within the system, while table 7 summarizes the known, involved processing steps and the information exchange between them.

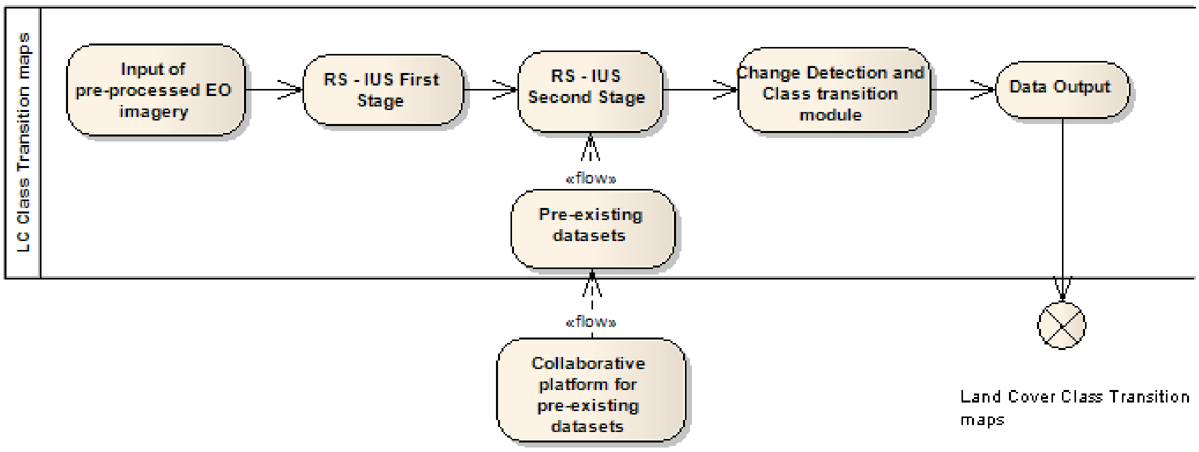


Figure 7: Workflow chain for the production of Land Cover Class transition maps.

Table 7: The involved processing steps for the delivery of LC Class transitions maps and the information exchange between them.

Known elements within EODHaM	Input information	Output information	Information exchange	constraints/ dependencies/ other information	Related Partners **(prime)**
Data Input	Pre-processed HR to VHR imagery		Selected Imagery to the RS-IUS First Stage	Orthorectified imagery (TOARF values)	PKH
Link to pre-existing datasets		Pre-existing data for the areas of study	Pre-existing data and metadata as inputs to the EODHaM 2nd Stage	Link to the collaborative platform that hosts the data and their metadata	CIBIO
RS-IUS First Stage	Pre-processed imagery	Preliminary classification map, spectral indices	Pre-processed data through the first stage of the RS-IUS	Fully automatic procedure	BACRES
RS-IUS Second Stage	Preliminary classification map, spectral indices, pre-existing datasets	LC/ LU maps	Preliminary classified map and ancillary data through the Second Stage of EODHaM		**IRD**,CNR, BACRES
Change detection and class transition module	Multitemporal LC/LU maps	LC Class transition maps	Multitemporal LC/ LU maps through the change detection and class transition		**CNR**, BACRES

			module		
Data Output		**LC Class Transition maps**			

5.2.6 Biodiversity indicators

Product Description: The Biodiversity indicators described in D2.1 (WP2), will be provided for all Natura 2000 sites. Following the European biodiversity targets and the work that has been done in EBONE project, three main indicators will be used for BIO_SOS: The extent and change of habitats of European interest in the context of a general habitat assessment; the abundance and distribution of selected plant species; the fragmentation of natural and semi-natural areas. Pressures can be added as far as they are spatially explicit.

Workflow description: Biodiversity indicators maps will be produced for all study sites. These maps will be obtained as final outputs in a processing chain consisting of the following elements:

- Data Input
- Link to collaborative platform
- RS-IUS First Stage (EODHaM 1st Stage)
- RS-IUS Second Stage (EODHaM 2nd Stage)
- EODHaM 3rd Stage
  - LC/LU to GHC and Annex 1 (and other habitat taxonomies for habitats not included in Annex 1 but existing in the Mediterranean sites considered in BIO_SOS) Habitat maps algorithm
  - Indicator extraction and trend evaluation algorithm
- Data Output/ Repository

The following diagram (figure 8) illustrates the product's workflow within the system, while table 8 summarizes the known, involved processing steps and the information exchange between them.

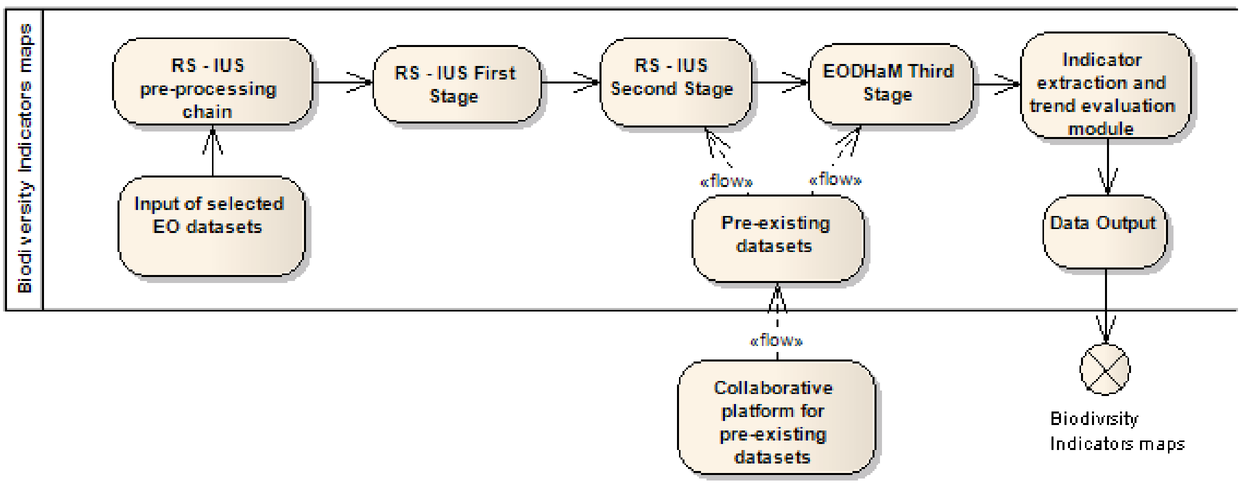


Figure 8: Workflow chain for the production of Biodiversity Indicators maps.

Table 8: The involved processing steps for the delivery of Biodiversity Indicators maps and the information exchange between them.

Known elements within EODHaM	Input information	Output information	Information exchange	constraints/ dependencies/ other information	Related Partners **(prime)**
Data Input	Pre-processed HR to VHR imagery		Selected Imagery to the RS-IUS First Stage	Orthorectified imagery (TOARF values)	PKH
Link to pre-existing datasets		Pre-existing data for the areas of study	Pre-existing data and metadata as inputs to the EODHaM 2nd and 3rd Stages	Link to the collaborative platform that hosts the data and their metadata	CIBIO
RS-IUS First Stage	Pre-processed imagery	Preliminary classification map, spectral indices	Pre-processed data through the first stage of the RS-IUS	Fully automatic procedure	BACRES
RS-IUS Second Stage	Preliminary classification map, spectral indices, pre-existing datasets	LC/ LU maps	Preliminary classified map and ancillary data through the Second Stage of EODHaM		**IRD**,CNR, BACRES
LC/LU to GHC and Annex1 habitat maps algorithm	LC/ LU maps, Preliminary classification map, spectral indices, pre-existing datasets	GHC and Annex 1 Habitat maps	LC/ LU maps through the conversion algorithm of EODHaM's Third Stage		**CNR**,CE RTH
Indicator extraction and trend evaluation algorithm	LC/ LU maps/ GHC and Annex 1 Habitat maps, pre-existing datasets	Biodiversity indicators maps	LC/LU and/or habitat maps through the indicators extraction and trend evaluation algorithm		**CERTH**, ATREE, CNR
Data Output		**Biodiversity Indicators maps**			

6. Service Chain Definition

The figure 9 illustrates the complete picture of EODHaM system with a higher level of abstraction. The following main characteristics of the system can be identified.

EODHaM is foreseen as a "system of systems" in the sense that each module (seperated in the scheme with dashed lines) will be an an independent executable that will work with none or minimum human interaction. Any independent software executable is a process. A process can transform data in either of two ways.

1) It can transform the structure of data (e.g., by reformatting it).

2) It can transform the information contained in the data.

In terms of both inputs and outputs, any process features

a) An input/output control flow. It carries no data, but controls the workflow through the flow of metadata.

b) An input/output data flow. Each input data set must be described in terms of file format, geographic coordinates, pixel size, processing level, etc.

As input data flow, every process (function or software executable) must be provided with a list of input parameters (variables). In the context of the BIO-SOS EODHaM system, which is an expert system, besides of defining the initial set of input data and parameters, processes shall be automatic. In practice, this means that input parameters of the single modules must be pointers to data sets (e.g. a pointer to a preliminary map, lidar image, optical image, etc.) or ancillary information (where ancillary information is defined as non-pictorial information which cannot be detected in RS imagery) exclusively.

Moreover, EODHaM will offer an "information function" that given the metadata of a set of input files, will respond on which outputs will be produced (a first approach of this functionality is introduced in the scheme with the metadata flow on top each module). Such an approach will give flexibility to the system by allowing for an "interactive workflow design", that means it enables the EODHaM system configurator, to explore unforeseen combinations of workflow steps in an easy way. Obviously some input data will be mandatory in order to make the module work (thus, each module should be accompanied with each specifications), but some may be optional or alternative. The parameters, that help a module to discriminate, which input files to include, may be for example (but not only): Sensor type; sensor resolution; region; extent, "type of information" etc.

To quantify the quality of outputs, EODHaM is planned to include an error measurement scheme which will provide the means to collect and propagate uncertainty information and error through the processing chains. This propagation should start from the metadata definition of the input data and add for each processing step the predefined precision ranges of each processing module for each identified parameter. Some of these uncertainties (for example numeric and geometric precision) can usually be expressed in fix ranges referred to the precision of the input data (min, mean and max error). Others may need subsequent manual validations in order to be evaluated, but the goal should be, that these validations have not to be executed for each processing, but only once in a while for an entire class of processing in order to become part of the ancillary data (or metadata) in input to the processing.

For the concrete case of habitat maps production, we foresee a workflow with four main stages (where each stage may be built of several modules with similar characteristics), a data input and a product packaging stage.

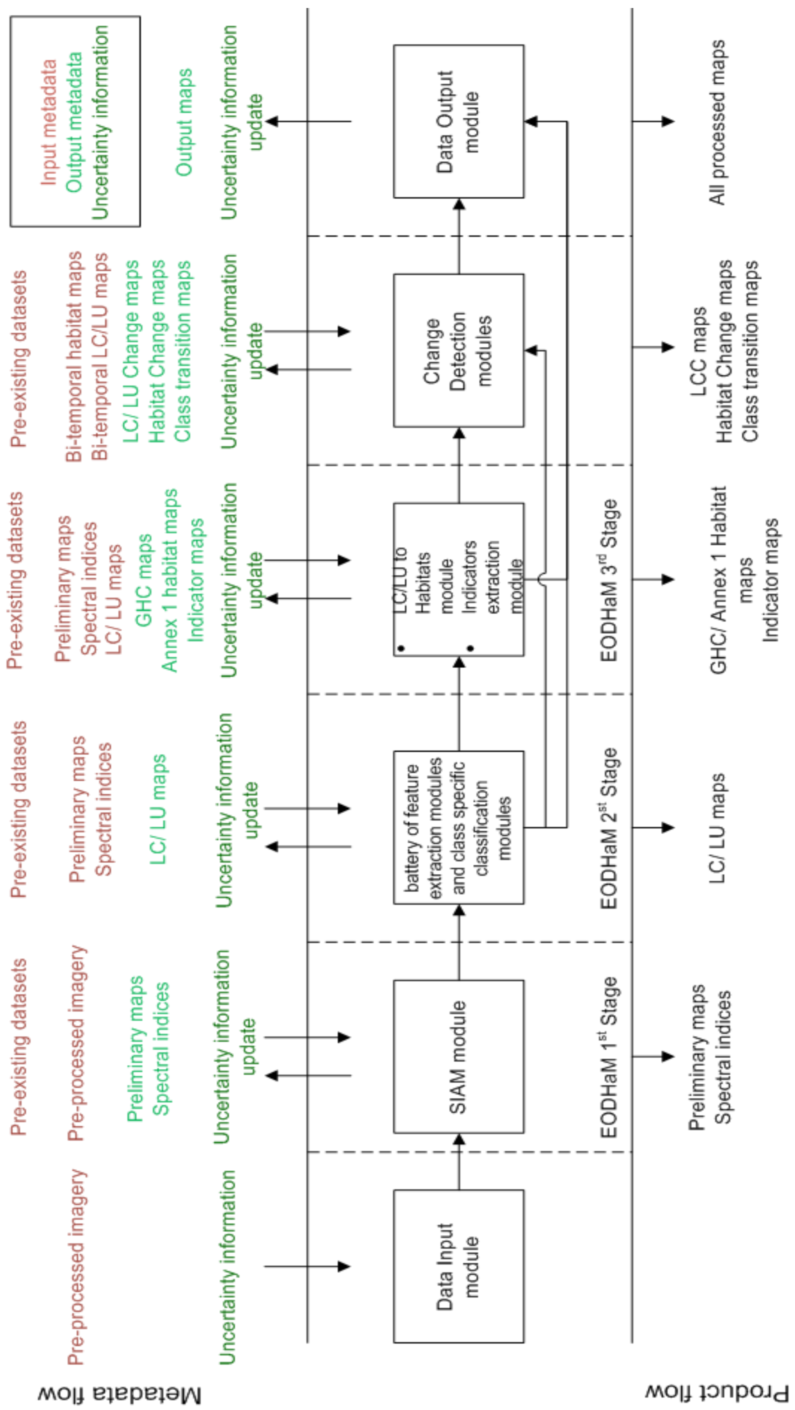


Figure 9: EODHaM's generic service chain

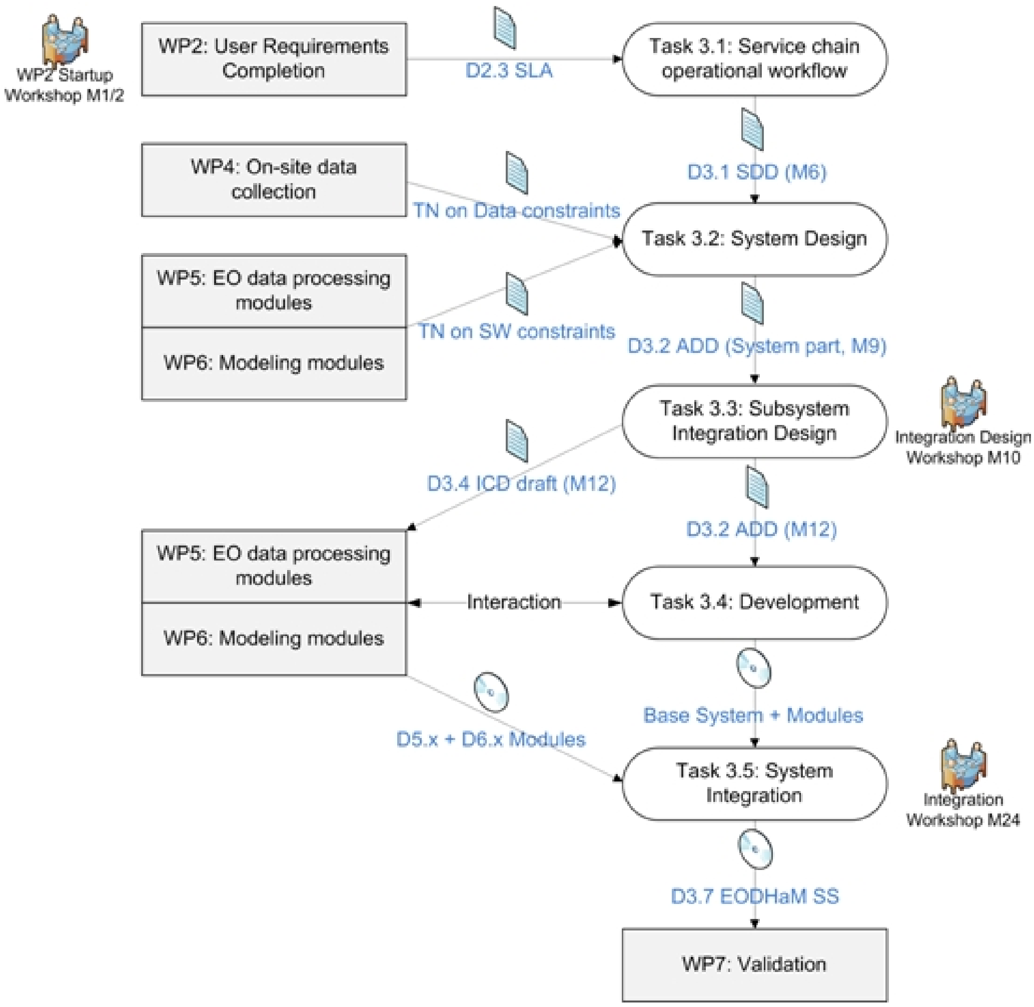
7. Appendices

Appendix I. Acronym and Abbreviation List

ATREE	Ashoka Trust for Research in Ecology and the Environment – India
BIO_SOS	Biodiversity Multi-Source MOnitoring System: From Space To Species
Cal/Val	Calibration and Validation
CEOS	Committee of Earth Observations
CERTH	Informatics And Telematics Institute Of The Centre For Research And Technology – Greece
CIBIO	Research Center in Biodiversity and Genetic Resources (Portugal)
CNR	Consiglio Nazionale delle Ricerche
DEM	Digital Elevation Model
DN	Digital Number
EBONE	European Biodiversity Observation Network
EO	Earth Observation
EODHaM	EO Data for Habitat Monitoring
EU	European Union
FAO	Food and Agriculture Organization
FAO-LCCS	FAO - Land Cover Classification System
FP7	Seventh Framework Program
GCP	Ground Control Point
GEOSS	Global Earth Observation System of Systems
GHC	General Habitat Categories
GLC	Global Land Cover
GMES	Global Monitoring for Environment and Security
HR	High Resolution
INSPIRE	Infrastructure for Spatial Information in Europe
LC	Land Cover
LCC	Land Cover Change
LCCS	Land Cover Classification System
LU	Land Use
MS	Multispectral
PKH	Planetek Hellas

PKI	Planetek Italia
QA4EO	Quality Assurance Framework for Earth Observation
QAP	Quality Assurance Plan
QI	Quality Indicator
RS	Remote Sensing
RS-IUS	Remote Sensing Image Understanding System
SDD	Service Design Document
SLA	Service Level Agreement
SRC	Spectral Rule-based Classifier
SURF	Surface Reflectance
TOA	Top Of Atmosphere
TOARF	Top Of Atmosphere Reflectance
VHR	Very High Resolution
WGCV	CEOS Working Group on Calibration and Validation
WP	Work Package

Appendix II. WP3 Workflow



8. References

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