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# EO-based monitoring of Europe's most precious habitats inside and outside protected areas

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## Abstract

In order to response to international commitments and to fulfill its own strategy to maintain biodiversity, Europe is in need for updated information on biodiversity in general, and the status of habitats and related threats and pressures in particular. The FP-7 project MS.MONINA responds to this need by fostering the use of European space and in-situ infrastructure and advanced Earth observationtechniques. The developed services address the three levels of implementation of the Habitats Directive (i.e. site-, state- and EU-level). They are specifically tailored to user requirements in terms of relevance, level-of-detail and scale, steadiness and reliability, uptake and fitness to existing workflows. Drawn from the experiences made in MS.MONINA, this paper presents achievements and open challenges of using EO technology to effectively monitor nature sites of community interest but also precious habitats outside the existing network of protected areas to reduce the loss of biodiversity.

## Keywords

Earth observation (EO), multi-scale, GMES/Copernicus, satellite remote sensing, Habitats directive, biodiversity monitoring

## (Guiding theme)

Where do protected areas, their regions and their networks currently stand regarding research and management?

## Europe in need of updated biodiversity information

The EU has set up an 'EU 2020 biodiversity strategy' in responseto the adoption of a global Strategic Plan for Biodiversity 2011-2020. Next to the general aim of "*halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020*", the strategy follows some specific objectives such as to "*fully implement the Birds and Habitats Directive*". The European Habitats Directive (92/43/EC, short: HabDir) is considered a flagship policy for the EU (WEBER & CHRISTOPHERSEN 2002), ascertaining the conservation of natural habitats, fauna and flora in the territory of the Member States (MS). Together with the Birds Directive (2009/147/EC) it is a highly effective legal instrument for nature conservation, as both directives are area intensive in the sense that they apply to the entire territory of the EU and consequently of each MS. The physical expression of this policy frameworkis a coherent ecological network of special areas of conservation known as NATURA2000. The purpose of the network is to assure the long-term survival of Europe's most preciousand threatened species and habitats across Europe.

HabDir foresees a reporting in regular intervals (currently every six years) to oversee the success of its implementation and to gain pan-European information on the status of biodiversity. This happens underdifferent territorial responsibilities:

The **EU,** responding as an entity to international commitments (UN Convention on Biological Diversity (CBD)and Bern Convention), requires MS to implement the HabDir in their national legislations; responsibility is transferred to the national level. Depending on their internal structure, the MS pass this responsibility on to lower administrative levels, e.g. federal states or provinces. The **MS** then need to aggregate information that is collected on **site** level, where the actual assessment takes place. While HabDir addresses the status of the entire MS territory, particular areas of protection are used as a means to directly enforce the directive (sites of community interest, SCIs). Whenever sites are on the edge of a country, the site border would follow the country's borderline.This may lead to trans-boundary effects to be observed in reporting, management practices, etc.

Within this ambitious setting, Earth observation (EO) techniques can obviously support the implementation of HabDir. Over the last years the technological framework has matured to such a degree that nowadays satellite remote sensing can offer objective (pre-)operational, yet economically priced solutions to provide timely information on pressures and impacts. It further helps toassignspatial priorities for conservation and tocollect long-term baseline data on multiple scales for evaluating the effectiveness of conservation strategies (LANG et al. 2012).

## EO-based monitoring capabilities

The growing need for the civilian use of satellite remote sensing and other EO technologies has led to the European programme GMES (Global Monitoring for Environment and Security). GMES, recently renamed to Copernicus (copernicus.eu), is a conjoint initiative between the European Commission and the European Space Agency (ESA). It builds on European space infrastructure and the technological capability to turn data into information services.For this purpose,ESA is developing five types of satellites, the so-called Sentinels, which will provide global coverage with radar and optical data with a few meters ground resolution. Additional data from satellites of the so-called contributing missions will increase both, the variety of available data types and the temporal coverage with remotely senseddata.

Reproducibility, objectivity, transferability and the increased possibility for quantification have been reported as the mainadvantages of mapping approaches based on EO data. Semi-automated classification methodologies for EO data provide a more objective outcome as compared to visual interpretation(LANG & LANGANKE 2006).Over the last years, great advantages have been reported in the use of remote sensing technology for the mapping and the assessment of habitats in Europe (for an overview see VANDENBORRE et al. 2011a). This likewise applies to different broad habitat types (forests, grasslands, wetlands, etc.) and different scales of observations as fine as sub-habitat level(LUCAS et al. 2011).

Advanced GIS modelling techniques can be used to derive probabilities for the presence of habitats in different biogeographical regions (FÖRSTER et al. 2007) and potential habitat ranges under specific assumptions or even changing conditions. In addition, spatial analysis techniques can be applied in order to quantitatively assess and compare structural parameters related to the actual conservation status (STRASSER et al. 2012).

## MS.MONINA –amultiscale EO-based monitoring concept

MS.MONINA (*Mulit-scale Service for Monitoring NATURA 2000 Habitats of European Community Interest*) fosters the use of GMES/Copernicus space and in-situ infrastructure and advanced EO-based analysis and modelling tools. The developed services are specifically tailored to user requirements in terms of relevance, level-of-detail and scale, steadiness and reliability, uptake and fitness to existing workflows. The project (www.ms-monina.eu) uses EO technology to effectively monitor nature sites of community interest but also precious habitats outside the existing network of protected areas to reduce the loss of biodiversity.

Three MS.MONINA (sub-)services are offered, reflecting the different levels of operation, i.e. .EU, .State, and .Site. This requires a concordant multi-user approach. Each of the service developments is tailored to the user and technical requirements that are specific for each level of implementation. User requirements surveys collect all details on existing work flows, data usages, and the responsibilities imposed by HabDir. Based on these requirements,the testing, comparison and integration of state-of-the-art methodologies is performed. Demonstrators, accompanied by a full-fledged user validation exercise, complete the service evolution plan and the final scoping towards market. MS.MONINA thereby addresses: (1) agencies on EU level, i.e. ETC Biodiversity, the EEA and DG Environment; (2) national and federal agencies in their reporting on sensitive sites and habitats within biogeographical regions on the entire territory; (3) local management authorities by advanced mapping methods for status assessment and change maps of sensitive sites; (4) all three groups by providing transferable and interoperable monitoring results for an improved information flow between all levels (VANDENBORRE et al. 2011a).

## A multi-scale service design

The 'multi-scale' concept, described below, matches with particular information needs on the hierarchical implementation scheme of HabDir. It also reflects on the hierarchical organization of ecological systems in general (LANG et al. 2011), ranging from single species detection (e.g. tree species discrimination, or grassland compositions, cf. SCHMIDTLEIN & SASSIN 2004) up to coarse scale mapping and modelling of broad habitat types and habitat probabilities. For these purposes, specific EO data are utilized, e.g. very high resolution sensors such as WorldView-2 for the site level and RapidEye for the state level.

Site-level service

While specific information needs at the local level obviously vary from one site to another, a general knowledge of actual habitat locations and distributions is required. Also, the conditions in terms of overall quality, existing threats and pressures need to be known, as well as their trend of development. Such up-to-date information is of high value to site managers, to make informed decisions about the measures to be applied, as well as the effects of such measures, in order to steer adaptations and improvements (VANDENBORRE et al. 2011b).

The MS.MONINA Site level service provides on-demand geo-spatial information on protected nature sites to various users, such as site managers, local and regional authorities. The service delivers a broad range of information outputs to fulfill various HabDir related requirements (e.g. Art. 17reporting, Standard Data Form reporting, site management, etc.) in all biogeographical regions of Europe. The suite of information products comprises among others: (i) wider landscape context maps, indicating e.g. overall landscape configuration or, fragmentation; (ii) maps of habitat patches and vegetation types (ranging from broad habitat groups to Annex I habitats and even subtypes); (iii) maps of conservation status of habitats and areas, based on meaningful indicators that can be derived from remote sensing of (e.g. tree encroachment in open habitats, invasive species, soil moisture, land use intensity); (iv) change detection maps of land cover, land use or conservation status indicators.

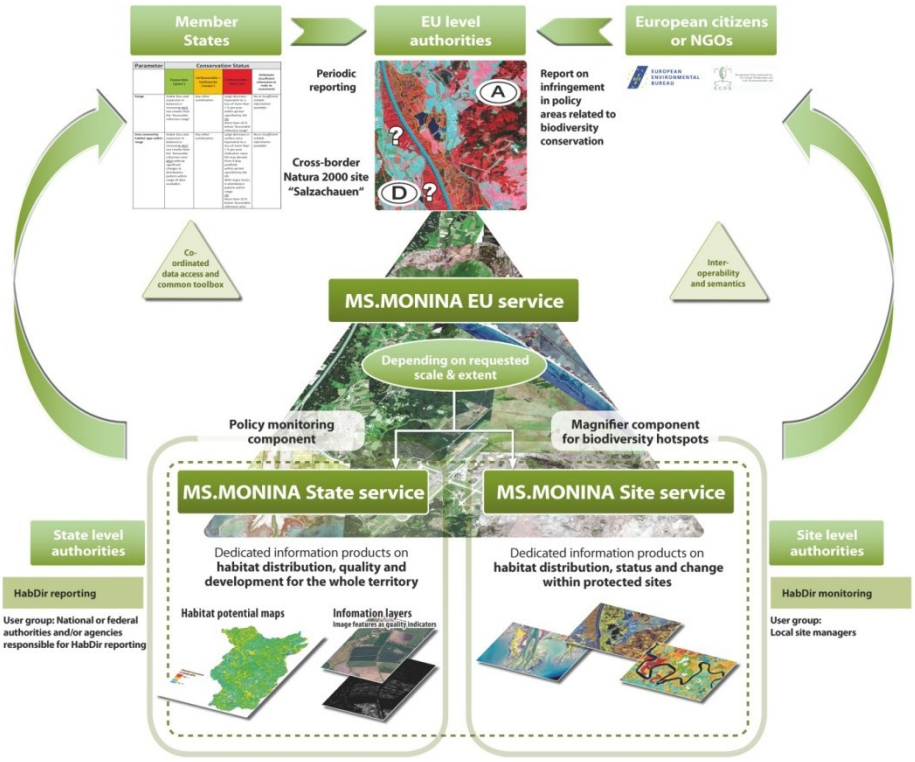



Figure 1: The overall, integrated service concept of MS.MONINA. On each level, the respective information services address specific authorities or management bodies. Depending on the primary roles assigned to the authorities by HabDir (Site level: monitoring, State level: reporting), dedicated information products are offered. The EU level service follows an on-demand logic.

State-level service

The MS.MONINA State service consists of an on-demand provision of geo-spatial information to support regional and national stakeholder activities related to the monitoring of precious habitats over the entire reporting territory (inside and outside of designated NATURA 2000 sites).Thereby,the State service establishes links to the Site level and the European level. To support the reporting obligations imposed by HabDir on MS level, theservice will utilise mapping and image analysis capabilities to provide critical information.The service is built around the concept of *information layers*that will act as 'containers' for relevant features such as vegetation stress, and should be easy to integrate into different systems with a common exchange format (LANG et al. 2012). The class features can be mono- or multi-temporal/multi-seasonal reflecting spectral, textural and structural information. The advantage is that thefocus is put on method development tackling habitat specific problems (e.g. shrub encroachment, temporal habitat variation, etc.) and that core image analysis models and components can be adjustedto service cases. In addition to the image analysis capabilities, expert models will be used to provide habitat potential maps. Based on a statistical modelling approach (maximum entropy model) the ecological niche of species and habitats is modelled based on abiotic factors (such as soil information, digital elevation models etc.). The resulting habitat potential maps can be included into image classification methods either by weighting the class probability or excluding classes due to a restricted natural potential of occurrence.

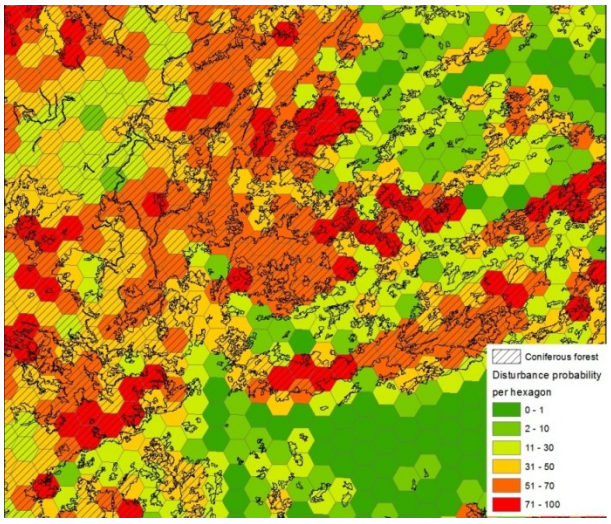



Figure 2: Hexagon-aggregated information layer on forest disturbance probability (Greek pilot site).Data source: RapidEye, analysed by different vegetation indices. Service provider: PLUS.

EU level service

The MS.MONINA EU service provides on-demand geo-spatial information to support EU stakeholders (e.g. DG ENV, EEA) activities related to: (1) the monitoring of biodiversity hotspots and (2) on-the-spot check of biodiversity reports and control of infringements to HabDir (e.g. activities which degrade and damage the habitat of the species). The concept is built around two main components (see Fig. 3): (i) **Magnifier component**: On-demand provision of habitat distribution and quality indicator maps for biodiversity hotspot sites (e.g. riparian areas, coastal areas); (ii) **Policy monitoring component**: On-demand provision of maps in "rush mode" as a means for external/independent validation of national biodiversity reports or to control infringement. Also on EU level, MS.MONINA makes use of remote sensing data for on-the-spot checks of biodiversity reports or for rapid mapping of protected sites (see Fig. 3).

When the service is triggered by EU mandated users, MS.MONINA examines the request, analyses the feasibility and the scale of the output products and accordingly tasks either the MS.MONINA Site service or the State service (cf.Fig.1).

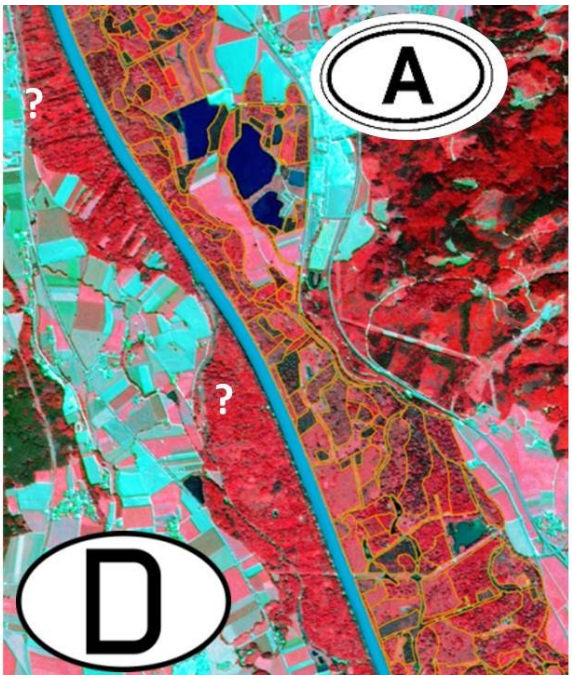



Figure 3: Trans-boundary NATURA 2000 site Salzachauen (Austria / Germany) – a case for the 'policy monitoring' component of the EU level service.

## Demonstrators and web dissemination platform

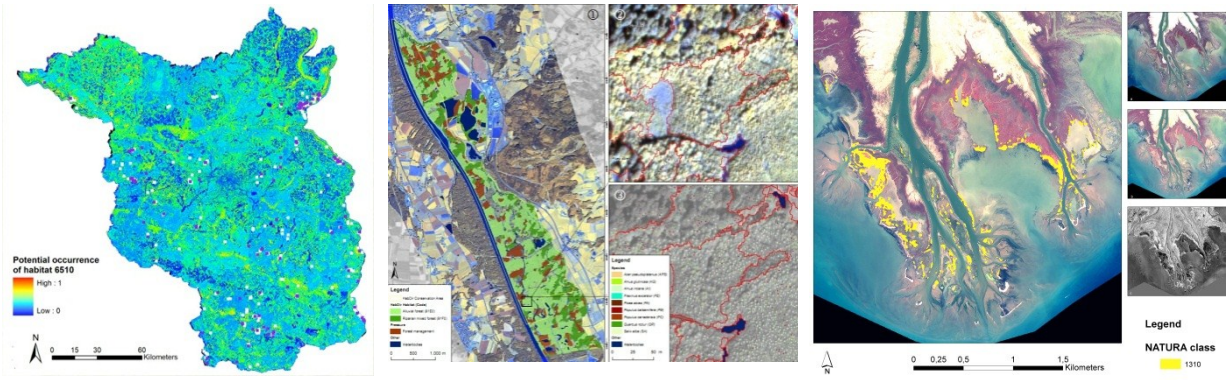
A key success factor of the GMES/Copernicus programme is to ensure the acceptance of services by users. This acceptance and further adoption requires high quality products that meet the specific information requirements of the user. MS.MONINA has selected a number of demonstrators as in-depth application scenarios of the services(see Tab. 1).In addition, a user validation exercise is currently carried out following a detailed validation protocol, which will demonstrate the potential and limitations in terms of methodological and technical achievements and the user involvement process.

Table 1: MS.MONINA demonstrators and related products on State and Site level.

| State Level | Biogeogr. region | Focus of the service | MS.MONINA products |
|---|---|---|---|
| Languedoc-Roussillon, Loire, Isére and Savoie region (France) | MED, CON, ALP | - Mapping lowland vegetation in open areas independently of the biogeographical region | - Heathland map<br>- Information layer for different types of grasslands based on their productivity |
| Federal State of Schleswig-Holstein (Germany) | ATL | - Strong focus on the information layer approach<br>- Landscape is characterized by lowland rivers and dominated by pastoral agricultural land use | - Grassland information layer including biomass, line structures, homogeneity, agricultural intensity, slope and slope direction<br>- Grassland classification including intense, dry, mesophile and wet grassland<br>- Wetland information layer including tree and shrub encroachment |
| Federal State of Brandenburg (Germany) | CON | - Good example for state modeler output<br>- Many special near-natural landscapes such as lowland fens, heathland and dry grassland | - Potential habitat map (range) for selected species and habitat types<br>- Information layer for heathland quality indicators |

| Site Level | Biogeogr. region | Focus of the service | MS.MONINA products |
|---|---|---|---|
| Salzachauen (Austria) | CON | - Mapping riparian forest habitats in a trans-boundary Natura 2000 site<br>- Habitat structure analysis | - Semi-automated object-based habitat classification<br>- Visual interpretation (EUNIS 3)<br>- Form, structure and core area analysis<br>- Seasonal changes in vegetation<br>- Monitoring of forest management measurements |
| Riesenferner-Ahrn (Italy) | ALP | - Mapping alpine habitats<br>- Conservation status assessment | - Classification processing chain for habitat mapping<br>- Processing chain for assessing conservation status for specific habitats based on shrub and tree encroachment |
| Döberitzer Heide, Kleine SchorfheideandKalmthoutse Heide (Germany, Belgium) | CON, ATL | - Knowledge-based heathland monitoring and change detection<br>- Monitoring of grass encroachment, shrub encroachment and dune fixation<br>- Conservation status assessment<br>- Biomass accumulation | - Semi-automated object-based habitat classification<br>- Automated classification of vegetation classes and habitat elements (indicator map)<br>- Maps of conservation status indicators in heathland and inland dune habitats<br>- Level of variation of structural elements within habitat patches (bare sand, dwarf shrubs, moss layer…)<br>- Map of changes in habitat type and conservation status |
| Axios and Aliakmonas (Greece) | MED | - Mapping river delta habitats<br>- Monitoring of conservation status<br>- Assessment of land use pressure<br>- Proportion of bare soil<br>- Surface area and trend of habitat type changes | - Wetland habitat maps using ANAX (Advanced classification methds for inventorying and mapping protected areas using satellite imagery) |
| Larzac foothills (France) | MED | - Mapping of habitats in a limestone karstic area<br>- Monitoring of conservation status<br>- Assessment of land use pressure (grazing, farming) | - Semi-automated object-based classification of habitats |

The maps shown in Fig. 4 illustrate three information products on State (Fig. 4a) and Site level (Fig. 4b and 4c).




**(a)** **(b)** **(c)**

Figure 4: (a) Habitat probability map for lowland hay meadows (6510) in Brandenburg (DE), service provider: Luftbild Umwelt Planung GmbH (LUP); (b) Habitat map for riparian forests (91E0*, 91F0) in Natura 2000 site Salzachauen (Austria), service provider: University of Salzburg, Z_GIS; (c) Freshwater habitat mapping (1310) in Natura 2000 site Axios delta (Greece), service provider: National Observatory of Athens.

A public access web platform showcases to the user community what can be offered by MS.MONINA. Thisincludes an online service portfolio with specifics on the offered services and further information on the MS.MONINAservice cases, an OGC-conform geoportal with all geospatial information products being delivered and a tools repository listing and cataloguing the methodological components and algorithms utilized by the partners for the image/geospatial analysis tasks.

## As a conclusion: from research to information services

Targets for the NATURA 2000 network are tough and reaching its ambitious goal will require extensive knowledge based on systematic and continuous data collection. However, many Member States are still lacking the ability to provide such information in a regular and routine fashion. Therefore, MS.MONINA will prepare the

ground for establishing services to support a successful implementation of the Habitats Directive on all levels(LANG et al. 2012).It will follow four important suitability criteria for such services as identified by VANDENBORRE et al. 2011: (1) multi-scale, i.e. addressing multiple scales on all levels of implementation; (2) versatile, with algorithms tailored to the habitat type of interest and differentimage types; (3) user-friendly, allowing integration of theproducts into existing workflows; (4) cost-efficient, providing reliable and reproducible products at an affordable cost, compared to traditional field methods.

MS.MONINA as a 3-years project aimsatpre-operational services that shouldstimulate the further development of GMES/Copernicus services in new emergingtarget areas such Biodiversity.These 'focus areas' can be considered areas of community concern, which dohave a strong policy-related, though less commercial motivation. Due to the fact that NATURA 2000 is already anchored in national legislation withspecific requirements, there are already companies (especially SMEs) which concentrate on marketstrategies in this context. Also, there are projects funded on national and supra-national scale, andresearch institutions have developed, together with users, concept and solutions for utilizing EOtechnology to support these requirements.

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