CHAPTER 6

Multi-scale service for monitoring Natura 2000 habitats of European Community interest (MS.Monina)

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ABSTRACT

Natura 2000, the European answer to the Convention on Biological Diversity (CBD), is one of the world's most effective legal instruments concerning biodiversity and nature conservation and a success story among pan-European initiatives. The EU habitats directive (Council Directive 92/43/EEC) requires standardised monitoring and reporting for which the project will offer an objective operational, yet economically priced solution. Users are in need of data and information, as imposed by the legally binding character of the directive. MS.Monina fosters the use of GMES space and in situ infrastructure and advanced EO-based analysis and modelling tools, 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 follows a pan-European, multi-scale approach on different levels reflecting the specificity and variety of habitats in the different biogeographical regions. The services are under final specification and first results of the project show the great potential of a multi-scale EO-based service ranging from biodiversity-related indicators to direct habitat mapping.

A MULTI-SCALE SERVICE TO SUPPORT THE EU HABITAT DIRECTIVE

MS.Monina operates on three interrelated user and scale levels for the successful implementation of the EU habitats directive (HabDir) and the linked Natura 2000 concept (cf. Vanden Borre et al., 2011a). Three (sub-)services are offered, reflecting these three levels of operation, i.e. MS. Monina EU, MS.Monina state, and MS. Monina site. Each of the service developments follows the same overall logic in three steps, but tailored to the (user) and technical requirements that are specific for each service level (Fig. 1). User requirements collect all details on existing workflows, data usages and

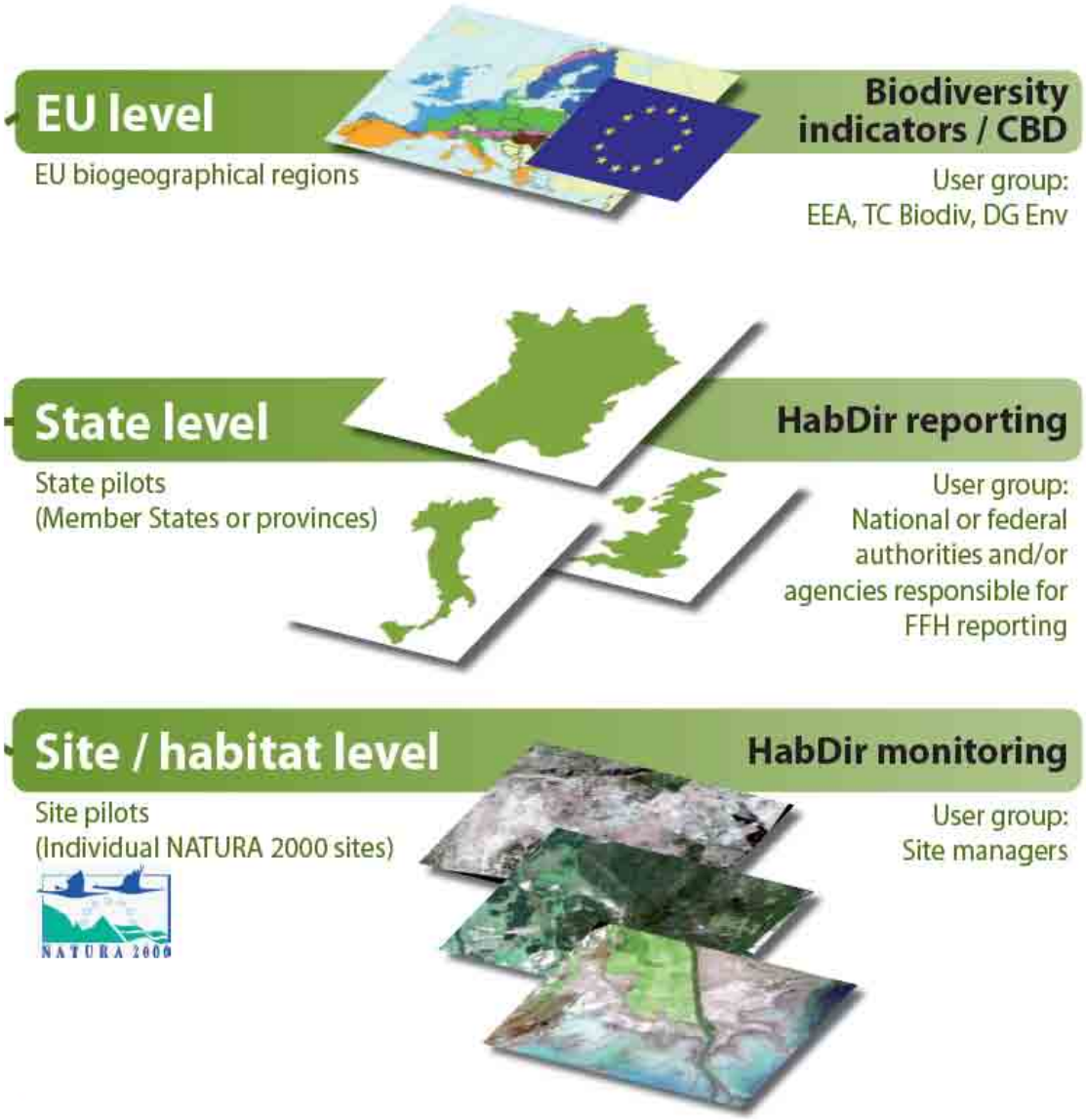

Figure 1. Specific needs for users on three levels of implementation © S. Lang

the responsibilities imposed by the directive. Based on these requirement specifications, testing, comparison and integration of state-of-the-art methodologies are performed, resulting in the actual development of the services. Demonstrators, accompanied by a user validation exercise, complete the service evolution plan and the final market scoping. In order to facilitate the uptake by users, an operational service is expected to fully integrate the recent potential of EO techniques and image analysis routines, but at the same time deliver conditioned information products (Lang, 2008) in a familiar and ready-to-use format. MS.Monina thereby addresses: (1) agencies at EU

level, i.e. ETC Biodiversity, the EEA and the Environment DG, in their reporting requirements to CBD-related environmental policies by providing added value information products on biodiversity status and following the wider SEIS developments; (2) national and federal agencies in reporting on sensitive sites and habitats within biogeographical regions on the entire territory by utilising advanced image analysis, modelling and information integration techniques; (3) local management authorities by advanced mapping methods for status assessment and change maps of sensitive sites and their surroundings in a spatial explicit manner; (4) all three groups by providing transferable and interoperable monitoring results for an improved information flow between all levels.

Four important criteria for such services to be suitable have been identified by Vanden Borre et al. (2011b): (1) multi-scalability, i.e. addressing multiple scales on all levels of implementation and enabling up- and downscaling between scale levels; (2) versatility, with algorithms tailored to the habitat type of interest and designed to best exploit certain image types; (3) user-friendliness, allowing seamless integration of resulting products into GIS-workflows already in place with users; (4) cost-efficiency, providing reliable and reproducible products at an affordable cost, compared to traditional field methods and other EO-based methods.

ACHIEVED RESULTS

Site-level service

While specific information needs at the local level obviously vary from one site to another, in general thorough knowledge of actual habitat locations and distributions is required, and 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 also 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 (Vanden Borre et al., 2011b).

The mapping sub-services could be grouped based on ecologically relevant characteristics of the output, in order to provide a user-adaptive structure for the final MS.Monina site service:

(1) maps and indicators on a larger scale, related to connectivity and landscape configuration;

(2) maps of patches of vegetation types or habitats;

(3) maps of conservation status of vegetations/areas, showing indicators;

(4) maps documenting land use/land cover changes.

Figure 2 shows a very basic information product, a pre-cursor to type (1), but with specific information on altered conditions in a Natura 2000 site, and under both aspects: improved and deteriorated habitat conditions. This is only a simple visual assessment using up-to-date EO data, but it already serves quite a few purposes from a site management perspective. Note that for illustration purposes, the map content has been zoomed to two particular areas, but otherwise includes information that covers the entire site.

Continental biogeographical region (BGR)		
Riparian forest habitats	91E0*, 9180*, 91F0, 9170	Object-based class modelling
Heathland and inland dunes	4030, 2310, 2330	Knowledge base, training pixels, training pixels are clustered and homogeneous signatures are created, maximum likelihood classification
Mediterranean BGR		
Lowland alluvial plains	7230, 7140, 6410, 6510, 6120, 6230, 3150, 9170	Classification algorithms are based on hybrid methods, exploiting both object-based and pixel-based approaches. Classification procedures include decision tree and supervised routines.
Benthic habitats	1150 *	Fusion of 3 models: a model of attenuation of the signal in its path through water, a spectral model of pixel unmixing, and a model of the underwater bathymetry
Freshwater habitats	(not specified)	Kernel-based reclassification (KRC) and support vector machines (SVM)
Atlantic BGR		
Lowland habitats	2310, 4010, 4030, 2330, 6410, 6510, 7120, 7140	Knowledge-based
Heathland and inland dunes	4010, 4030, 2310, 2330, 2110, 2120, 2130, 2150, 2160, 2170, 2180, 2190	Supervised classification in combination with ecologically based knowledge decision rules
Alpine BGR		
Alpine forests	(not specified)	Supervised classification, maximum likelihood approach. Change classification
Alpine habitats	4060, 4070, 6150, 6170, 6230, 6430, 6510, 6520, 7140, 7240, 8110, 8120, 9410, 9420	Stratified sampling, ensemble classifier (e.g. maximum likelihood, See 5, support vector machine)
Cross-biogeographical		
Indicator *Bush and tree encroachment*	5210, 6210, 6220, 8210, 92A0, 9340	Object-oriented classification (Boolean or fuzzy membership functions)
Indicators *compositional variation in (semi-) natural plant assemblages; α, β- biodiversity measures*	Inland dunes (2xxx), heath and scrub (4xxx), grassland formations (6xxx) and raised bogs (7xxx)	Ordination methods to extract major floristic gradients. linkage hyperspectral imagery by partial least-squares regression

Table 1. Specificities of site-level pilots listing ecosystems, N-2000 habitats addressed, and image analysis methods applied (partly also applicable at state level)

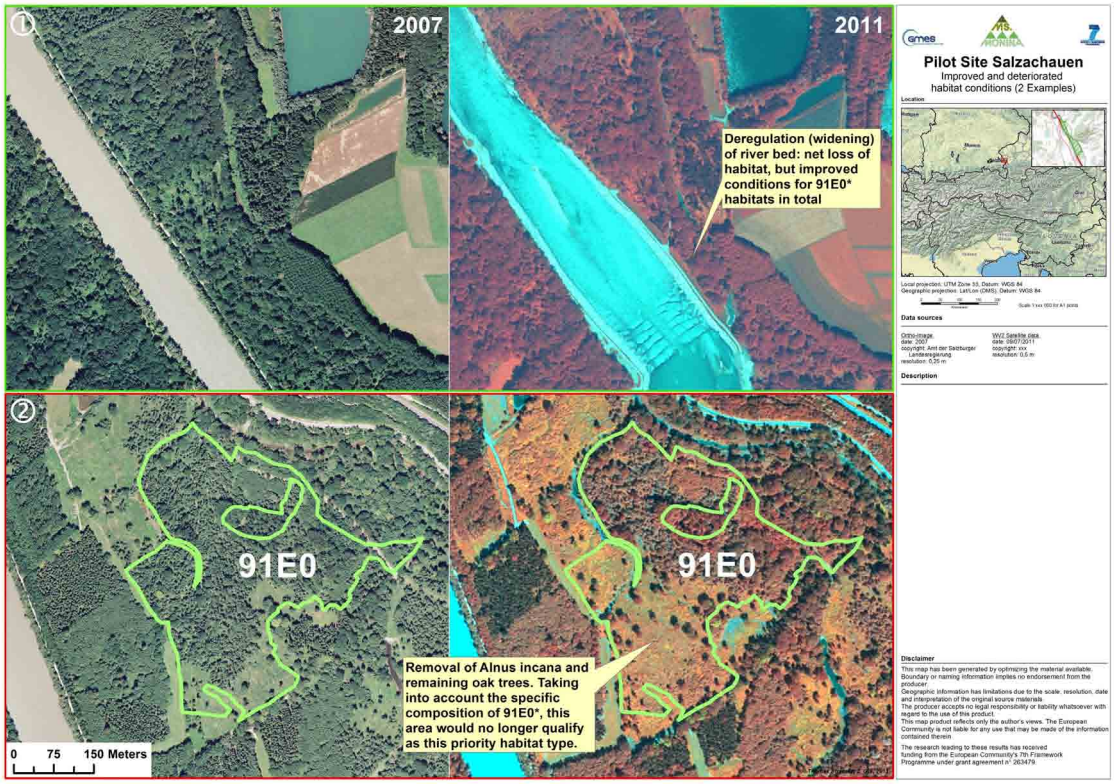

Figure 2. Pilot site Salzachauen, 'zoom' to critical changes in habitat conditions (© PLUS/Z_GIS; orthophoto: Federal state of Salzburg; habitat delineation: Revital; figure composition: T. Strasser)

State-level service

The MS.Monina state service establishes integrating links to the regional/site level and the European level. To support the reporting obligations imposed by HabDir, this service will utilise mapping and image analysis capabilities to provide critical information, even outside the network of protected sites. The service cases require adjusted developments (local user needs, biogeographic conditions, partner expertise, tools, etc.). Methods should be transferable to other service cases and a (technical) exchange between service cases and partners should be possible. To make this possible, a concept of interpretation layers has been developed. The idea behind this is that new data analysis methods could be potentially applied in several service cases. These interpretation layers will act as a 'container' for relevant class features, and should be easy to integrate into different systems with a commonly known exchange format. The features can be mono- or multi-temporal/multi-seasonal reflecting spectral, textural and structural information. The advantage is that a focus is put on method development tackling habitat-specific problems (shrub encroachment, temporal habitat variation, etc.) and that core image analysis models and components can be tuned to service cases. Class model developments in thematically overlapping service cases can then 'learn' from each other.

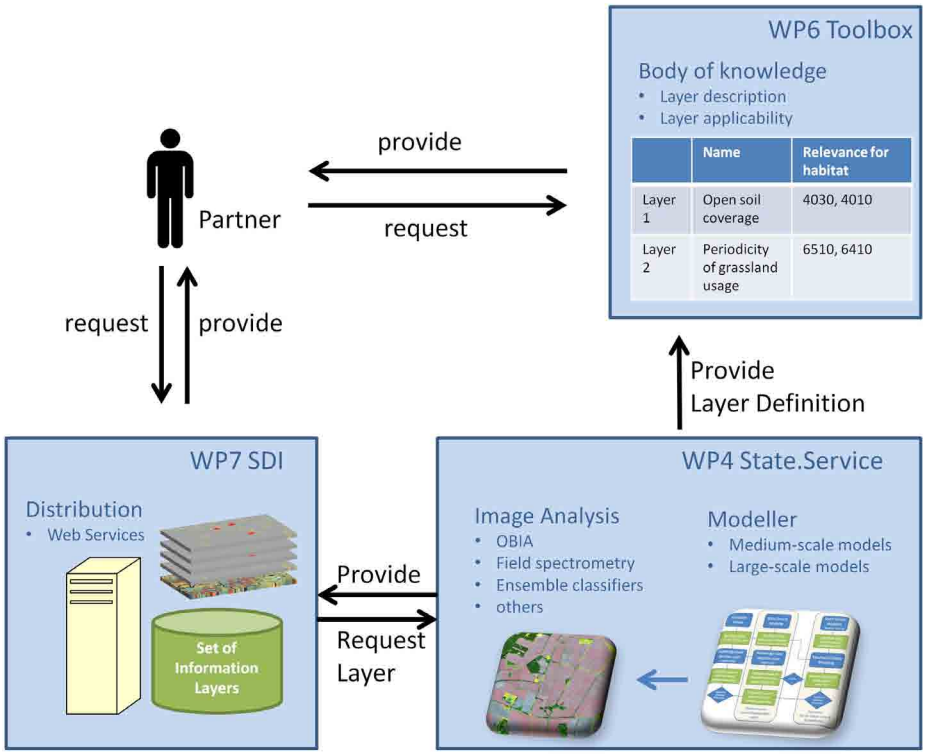

Figure 3. Interpretation layer concept with interlinkages to the MS.Monina SDI and toolbox
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EU-level service

Based on the Member States' reports, the European Commission compiles a 6-yearly composite report with an overview of the actual conservation status of all habitats and species protected by the HabDir. Data are integrated to the level of nine biogeographical regions (Atlantic, Continental, Alpine, Boreal, Mediterranean, Macaronesian, Pannonian, Steppic and Black Sea), to reflect the large variety in environments across the European continent. The latest composite report appeared in 2009 which had to face the challenge of lacking harmonisation in data collection and reporting among Member States (Vanden Borre et al. 2011b). The EU-level service will support the requirements from EU administration for independent, complementary information in two ways: (1) biodiversity indicators which are derived from pan-European products including the GIO high-resolution layers (HRL), on e.g. forest, grasslands, wetlands; and (2) selected local level information for validating specific ambiguous cases.

Multi-scale service chain

The multi-scale approach will be realised and demonstrated through vertical service chains. There are many possible hierarchical relations between the EU (on top), the individual protected sites (on the bottom), and Member States in between, located in different biogeographical regions. Connected

vertical elements (e.g. EU–Member State A–sites *b, c*) together outline a service chain. Service chains are hence formed by 'trans-level' applications within BGR, complemented by the EU level. To reach from site level monitoring to Member State-relevant information, upscaling methods need to be coupled with additional tools. Habitat modelling techniques will be utilised and combined with advanced analysis techniques of satellite data at different spatial resolutions (very high to high) using e.g. object-based image analysis. By this, the 'multi-scale' concept of the Natura 2000 implementation mimics an ecological scaling ladder with a focal level embedded in a nested hierarchy (Lang et al., 2011).

Service level agreements with different user groups

Next to the actual service developments, the project consists of a number of supportive tasks to ensure the interoperability and information and data flow between the three service levels. The framework for this is provided by the user engagement programme. Dedicated user workshops are held and interviews are conducted that lead into service level agreements (SLAs) to specify the information demanded. Demonstration of the service cases in the respective pilots as well as a validation exercises also belong to the user-oriented activities, which are considered crucial for the success of this GMES project.

EO data acquisition

The EO data management is a crucial task within the project and involves the data acquisition procedure utilising the GMES Data Warehouse. For the first year, VHR data has been ordered for 21 sites within two acquisition windows: the first from June to July 2011 and the second in September 2011, whereas the first had to be extended to August 2011 to allow for further acquisitions. The results are very satisfying with scenes for 15 sites in the first acquisition window and only two rejections, due to cloud cover. Data acquisition was not successful for three sites. In the second acquisition window, data has been acquired for 11 sites. All data are provided by WorldView-2 (0.5 m/pix ground resolution), most with eight bands. Additionally, multiannual HR datasets covering more than 130 000 km^2 have been obtained from the RapidEye data archive.

Tools repository, SDI and interoperability

Available tools and methods for habitat mapping and monitoring are collected from different sources and put into a common knowledge database, the 'Body of Knowledge' (BoK), where functionality, architecture and validation state of the tools are described. A comprehensive compilation of different in-house and/or open methodological tools has already been undertaken and the tool repository has been set up and is now accessible for registered users.

For discovery, viewing and access of MS.Monina products (spatial data and services) an operational interface is set up by developing a project specific spatial data infrastructure (SDI) portal. This portal adheres to Inspire standards and realises semantic interoperability issues. Possible technologies and solutions for the SDI have been identified and the development of an SDI prototype has already started, mainly building on open source software components. Specific challenges for the

SDI are the diversity of data sources (raster/vector, file formats, coordinate systems, etc.) and the design of an efficient, easy-to-use workflow to ingest data and metadata in one pass. Metadata profiles suitable for nature conservation have been identified. With respect to interoperability issues, ontology has been developed containing selected classes to define necessary indicators. Semantic properties like habitat types, plant species, water activity, soil, coverage and temperature are included and semantic relations between classes have been generated. Remote sensing indicators of state and EU-levels can be introduced when output data structure and classification methodology were defined.

Links to related (past or ongoing) activities

Experiences from the Belgian Belspo-funded project Habistat serve as a foundation to build on. The geoland2 core information services (CIS), particularly agri-env, water, forest and spatial planning, are likely to work in a complementary fashion to MS.Monina, resulting in the sharing of products and services. The SATChMo core mapping service offers the opportunity to test or extrapolate MS.Monina outputs in order to be representative for the whole of Europe. At state level, cooperation with national GMES-related projects like DeCOVER is foreseen to ensure a knowledge exchange for state-specific requirements. MS.Monina will also complement the efforts taken in EBONE (in terms of data gathering, indicator usage, and institutionally in terms of mandates and capacities) and Nature-SDI*plus* (in terms of data infrastructure, data models, and best practices of geodata handling in general). The Nature-SDI*plus* metadata profile has been adopted, as it is specifically developed for nature conservation. In a complementary way, MS.Monina links up with BIO_SOS and the other funded pre-operational services that strive to explore new emerging areas for GMES services in support of natural resource protection and management. It interfaces Interreg project HabitChange in terms of adaptive management for changes due to external drivers.

CONCLUSIONS

MS.Monina, in its multi-scale approach, will demonstrate to users the benefit of using services based on EO data. Therefore it will set the crucial conditions for a significant uptake of products and a long-term sustainability of the services. The general goal of the user communities is to feed their decision-making process on status evaluation with indispensable information. Such information is currently largely lacking or very expensive and time-consuming to obtain (i.e. almost exclusively by field work). At site level, managers will use MS.Monina services to find out where habitat status is deteriorating or habitats are even disappearing, and what internal or external pressures and threats cause these deteriorations. Site managers are expected to use this knowledge to make informed decisions about where to apply dedicated management measures in order to obtain an optimum result, and will later on be able to monitor the effects of this management. At EU and state levels, the services will be used to evaluate policies at different scales and adapt them when necessary.

Ultimately, to reach European citizens, stakeholders and entrepreneurship, the project promotes activities aiming at

communicating, integrating, sharing knowledge and disseminating achievements, building on the momentum generated at the close of the International Year of Diversity, in December 2010.

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