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Towards a Wider Uptake of Remote Sensing in Natura 2000 Monitoring: Streamlining Remote Sensing Products with Users' Needs and Expectations

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***Abstract*-The implementation of the Habitats Directive (HabDir) in 1992 has been a major step towards a more harmonized approach to nature conservation in the European Union (EU). Member states granted legal protection to habitats and species listed by the HabDir, and designated areas of high nature value as Natura 2000 sites. But legal designation and protection is not enough: sites need to be managed appropriately, and the impacts of environmental pressures working on them require careful monitoring. Furthermore, member states need to monitor the conservation status of habitats and species on their entire territory, and report this to the EU on a six-yearly basis. These reports then serve as input for an assessment at the European scale, aiding the EU to follow up on achievements of the HabDir, and to adapt policy where needed. As a result, this shift towards a more systematic and knowledge-driven approach to biodiversity policy in the EU led to extensive and diverse data needs, at three different scale levels (EU, member state, and protected site) and involving many stakeholders. This can no longer be met by field work alone. Remote sensing image analysis has been demonstrated to be a powerful tool to assist in fulfilling the growing data needs, yet its use in operational Natura 2000 monitoring is still limited. We argue that a successful remote sensing based service for habitat monitoring in the Natura 2000 context should be: (1) multi-scale, (2) versatile, (3) user-friendly, and (4) cost-efficient. The recently started FP7-SPACE project MS.MONINA intends to set the basis for such a service, complying with pan-European efforts for data harmonization and exchange (GMES, INSPIRE, SEIS), and relying on a strong user involvement.**

INTRODUCTION

In 1992, the European Union (EU) adopted the *'Council Directive on the conservation of natural habitats and of wild fauna and flora'* (Habitats Directive 92/43/EEC; HabDir), as an implementation of the 1979 Bern Convention on the Conservation of European Wildlife and Natural Habitats [1]. The general goal of this directive is to contribute to the conservation of natural habitats and of wild fauna and flora in the European territory of the member states. With its adoption, the EU set the scene for a more systematic, harmonized and target-oriented approach to nature conservation than ever, spanning the whole EU-territory. The HabDir's annexes listed several rare and threatened habitats and species, with the aim to assure their long-term survival by bringing and maintaining them in a favourable conservation status. It soon became clear that reaching its ambitious goals would require extensive knowledge based on systematic and continued data collection, but in many member states even basic data were, and in some cases still are, largely lacking [2].

Remote sensing (RS) has long been recognized as a powerful tool for data collection to serve biodiversity conservation, and recent advances in image acquisition (such as hyperspectral, LiDAR) and information extraction (e.g. fuzzy classification, object-based image analysis) have further enhanced its application potential [3]. However, as shown by [4], its use in the specific context of Natura 2000 monitoring and conservation remains very fragmented and limited to exemplary cases, demonstration projects and short-term research projects. An important challenge lies in integrating and extending the achievements of these small-scale projects into a full-grown service that addresses the continuing data needs and propagates the potential of RS into new and ongoing operational Natura 2000 monitoring schemes.

In this paper, we present a short introduction to the legal framework of Natura 2000 and the data needs that stem from it, before proceeding to the potential advantages as well as shortcomings of RS in fulfilling these data needs, and the prerequisites to its use. Finally, we mark the contours of a future service for Natura 2000 monitoring using RS, which will be developed in a recently started FP7-project, MS.MONINA.

NATURA 2000

In order to achieve the aims of the HabDir, member states have to bring or maintain the habitats and species of its annex-

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es that are present on their territory in a favourable conservation status. The latter concept refers to a situation where these habitats and species are prospering, and have good prospects to continue to do so in the future [5]. More specifically, member states have an obligation to: (1) designate and protect Natura 2000 sites where targeted habitats and species occur (Art. 3 and 4 of the HabDir); (2) set up monitoring programmes to follow the status of these habitats and species on the member state's territory (Art. 11); and (3) report the findings of these monitoring schemes to the European Commission on a six-yearly basis (Art. 17). Ref. [4] analysed the data needs on habitats stemming from these obligations, and found that they can be grouped at three spatial levels: a local (site) level, a national (or in some countries regional/sub-national) level, and the EU-level.

A. Local level: the Natura 2000 network of protected sites

Since the implementation of the HabDir, the important concept of establishing a network of 'Sites of Community Interest' has been widely recognized as an innovative and powerful means to implement biodiversity conservation in the spirit of the United Nations Convention on Biological Diversity (UN-CBD). The so-called Natura 2000 network consists of natural sites across Europe, that harbour prime examples of Europe's rarest and most threatened habitats and species, as identified in the annexes to the HabDir. At present, the network has over 25,000 sites, protecting around 755,000 km² (17.6%) of the terrestrial area of the EU [6].

Inclusion of sites in the network entails amongst others the obligation for member states to grant the site legal protection, to take appropriate conservation measures, and to avoid any negative impact from activities within or near the site on the habitats and species in the site. Therefore, any such planned activities, whether within or outside the site but with potential negative effects on the site, have to be subjected beforehand to an appropriate assessment, and can only be carried out if no negative effects are expected, or if sufficient mitigation and/or compensation measures have been taken to avoid any negative effects on the network.

Data needs at the local level are very diverse and vary from one site to another. In general, a proper implementation of the obligation of appropriate assessments requires a thorough knowledge of habitat locations and species occurrences in the site (i.e. up-to-date distribution maps), as well as information on their quality, abiotic conditions, existing pressures,… Such data are also of high value to managers, to make informed decisions about the measures to be applied. Furthermore, managers also want to monitor the effect of the measures they have taken, in order to allow adaptations and improvements where it is necessary.

B. National (regional) level: the Art. 17 reporting

According to Art. 11 of the HabDir, member states have to monitor the conservation status of the protected habitats and species on their territory, and report their findings to the EU in a six-yearly report (Art. 17).

The conservation status is assessed in terms of the range, area, quality (formally: 'specific structures and functions') and future prospects for habitats, and the range, population, presence of suitable habitat, and future prospects for species. Each of these parameters is assessed using a traffic-light scheme (green/amber/red, corresponding to favourable / unfavourable: inadequate / unfavourable: bad). The integration of the outcome of the four assessed parameters leads to an overall assessment of the conservation status of each habitat and each species, using the same traffic-light scheme.

A non-negligible detail is that this assessment needs to be representative for the state of habitats and species in the whole territory of the member state. Therefore, it should be based on data drawn from the entire country (including outside protected sites), and cannot be restricted to the Natura 2000 sites or other protected areas alone. Authorities need to set up monitoring programmes that will provide them with a clear picture of the nationwide (or regionwide) distribution of habitats and species, status and trends of the total habitat area or species' population size that is present on their territory, the habitat quality (or for species: the amount and quality of the habitat considered suitable for the species), and pressures and threats that have (or may have in the near future) an impact on the habitats or species.

C. EU-level: the biogeographical assessment

Drawing from the member states' reports, the European Commission compiles a six-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 [7]. However, efficient data integration was severely hampered by a lack of harmonization in data collection and reporting among member states [8].

REMOTE SENSING AS (PART OF) A SOLUTION?

It has been widely acknowledged that RS can offer numerous advantages for biodiversity monitoring over more traditional, field-based methods [9-14]. First, it delivers a spatially exhaustive and consistent view of the Earth's surface over larger areas, including locations that are remote, very sensitive for disturbance, or otherwise inaccessible. Second, it is the only means by which full-coverage measurements of quantitative data over larger areas can be obtained, e.g. on biophysical (Leaf Area Index, Net Primary Productivity,…) or abiotic (soil moisture,…) properties. Field work, on the contrary, can only deliver similar information through point sampling and subsequent spatial interpolation. Third, the potential for frequently repeated measurements, and the faster (less labour- and time-consuming) process of information extraction, allow for more frequent updating of maps and products, and hence for more intensive monitoring. Fourth, unlike in field work campaigns, where a mapping typology is usually defined in advance, the data acquisition process of RS does not require any a priori interpretation. This allows for more flexibility in information extraction, while at the same time promoting better documenting and higher repeatability of the applied analyses. The latter

in turn provides for a more reliable detection of changes between products with different time-stamps. Finally, the existence of image archives dating back several decades may, at least for some areas, enable a retrospective evaluation of changes that have occurred up till now.

Despite its potential benefits, the adoption of RS by biologists and ecologists in general is lagging behind [14-18], and this is also seen in the applied field of Natura 2000 habitat monitoring [4]. This may at least in part result from several constraints that limit the possibilities of RS for this specific application field, namely:

(i) the appearance of some habitat types strongly differs across Europe, with often different dominant species, hampering a uniform classification approach on a European scale;
(ii) conversely, some vegetations that look very similar belong to different habitat types, and can only be identified correctly by the presence of (often rare) indicator species;
(iii) habitat quality assessments are often based on the occurrence of key species, or other fine-scale indicators, that pose major challenges to detect with RS;
(iv) the scale strongly varies among habitat types, with some habitat types (e.g. estuaries) occupying vast areas of hundreds of km², and others (e.g. depressions on peat substrates) typically confined to small linear or point elements of only a few m². With such scale differences, choosing an optimal pixel size is problematic.

As a result of these difficulties, detailed habitat mapping usually requires advanced technologies (e.g. hyperspatial, hyperspectral, LiDAR) that in many cases cannot yet be obtained from satellite platforms. Nevertheless, successful examples of RS for Natura 2000 exist (e.g. [19-25]), but they seem to be struggling to evolve from research and demonstration projects into full operational application. The uptake of RS methods in the workflows of the Natura 2000 monitoring community appears to be a critical point, and the costs of suitable data may well be an important cause of that.

In order to gear developments in RS to the users' needs and expectations, and hence facilitate the uptake by the users, an operational service should be set up that exploits the potential of various RS data types and state-of-the-art analyses, but delivers information products in a format that users are familiar with. We put forward that a RS based service for habitat monitoring in the Natura 2000 context should fulfil four important criteria. Such a service should be:

(1) *multi-scale*, i.e. address multiple scales (EU – member state – site), depending on the intended user, and enable easy data flow (up- and downscaling) between different scale levels;
(2) *versatile*, i.e. consist of a wide set of algorithms, tailored to the habitat type(s) of interest and designed to get the best possible out of a certain image type(s);
(3) *user-friendly*, i.e. make preferable use of attainable source data (image, field), and allow seamless integration of resulting products into GIS-workflows already in place with users;
(4) *cost-efficient*, i.e. provide reliable and reproducible products at an affordable cost, compared to traditional field methods and other RS based methods.

TOWARDS A BETTER INTEGRATION

Today, with (i) GMES (Global Monitoring for Environment and Security) as an umbrella for utilizing the latest achievements from both space and in-situ sensors, (ii) the INSPIRE Directive as a pan-European endeavour of obeying standards and other prerequisites of interoperable use, and (iii) the vision of a unified and integrated Single European Information Space (SEIS), the stage is set for a technologically mature, integrated, and user-centric system of services, more effectively to be used than ever. The FP7-SPACE funded GMES project MS.MONINA (Multi-scale Service for Monitoring NATURA 2000 Habitats of European Community Interest) intends to demonstrate and set the basis for such a service, with the following key characteristics:

- The service is oriented towards stakeholders on three levels (site, member state, EU), addressing their needs for HabDir reporting, monitoring and management.
- It complies with pan-European efforts (GMES, INSPIRE, SEIS) for data harmonization and exchange, to the benefit of users and service providers, and allows maximal data exchange between different levels by providing a multi-scale interoperability of the products.
- It applies integrated mapping approaches using the full spectrum of available optical RS data sources and additional in-situ information to map and to monitor protected habitats from the local to the national level. Hence, it will not be a one-fits-all methodological solution, but an integrated network of methods that can deal with the versatility in image data and habitat types across Europe. Next to providing high-standard products fulfilling current information needs, such an approach enables (future) integration of new methods to deal with the ever-changing ecological insights into habitat assessements, and provides flexibility that allows for (future) recasting of basic measurements into the desired data products and information.
- On both the EU and member state levels, it supplements the monitoring of currently protected areas by spatial modelling of potential occurrences (and its changes) of species or habitats – in particular outside protected areas, based on (as much as possible EU-wide) harmonized geodata (e.g. soil, hydrology, climate, products derived from the GMES Land Monitoring Core Service,…).
- A dedicated user engagement programme based on service level agreements (SLAs) and demonstration of service cases and pilots, as well as a user-driven trans-level validation exercise, will ensure user-friendliness and cost-efficiency of the service, and facilitate its uptake by the user community.

The project will integrate the information provided on each of the three levels through vertical service chains (Fig. 1). This goes beyond statistical up- or downscaling because requirements on each of the levels differ, but should reveal a more complete picture on the successful implementation of the HabDir in the end. The responsibilities on member state or EU level require more than collecting data from the respective lower levels. To reach from site level monitoring to member

state relevant information, up-scaling methods need to be coupled with additional tools. Habitat modelling techniques will be utilized 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. Up-scaling along a hierarchical ladder will support the 'conditioning' of biodiversity information on higher administrative and responsibility levels with their specific requirements according to the HabDir.

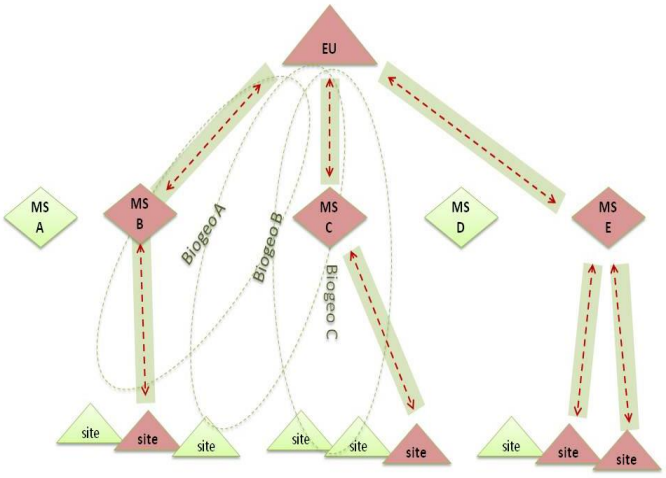

Fig. 1. The interplay of the different levels for integrated multi-scale information provision. (EU: European Union; MS: member state; Biogeo: biogeographical region).

CONCLUSIONS

Despite the great potential of RS, its use in Natura 2000 habitat mapping and monitoring has hitherto been limited. We argue that a RS based service needs to fulfil a number of criteria to be successful in this field of application. The FP7-project MS.MONINA intends to set up such a service, but this will just be a first step. Further work from both communities (remote sensing and ecology) will be needed to narrow the gap and strengthen the operational use of RS in Natura 2000 habitat monitoring.

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