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Editorial

Earth observation for habitat mapping and biodiversity monitoring

Safeguarding biodiversity: a case for 'glocalized' information

Biodiversity – the variety of life forms and our "*natural capital and life-insurance*" (European Commission, 2011) – is on decline (Isbell, 2010; Trochet and Schmeller, 2013), with consequences on ecosystem function and stability, and ultimately human well-being (Naeem et al., 2009). Since 1992, the International Convention on Biological Diversity, short CBD, has bundled the United Nations' joint effort to halt or at least lower the accelerated loss of biodiversity, but indeed it remains one of the key global challenges that requires a concerted, effective use of latest technology. As by the end of 2010 (the "International Year of Biodiversity") the global society became aware that the ambitious goal of "halting biodiversity" has not been reached, the importance of both observation and technology development became even more important.

Safeguarding the integrity of species and ecosystems is a global challenge with continental, regional, and ultimately local implications – with biodiversity being a *glocalized* phenomenon. Geographically this manifests in a hierarchy of scales, from biomes, over (systems of) ecosystems down to communities, populations and species. The spatial variability of critical parameters at each hierarchical level can be used as an indication of current state and conditions, distribution, and temporal dynamic of biodiversity. Observing and monitoring aspects of biodiversity, at any level and scale, can thus be approximated by analysing the composition, variability and changes of tangible entities (i.e. habitats) and their spatial patterns (Bock et al., 2005). Remote sensing technology has the capacity to provide spatially explicit information relevant to the multi-scale perspective required by ecologists (to investigate the relationships between pattern and processes) and land managers (to design and implement conservation actions). This information thus complements data obtained through standardized, in situ surveys related to very local aspects of biodiversity, by representing integrated higher-level characteristics such as those of *ecological neighbourhoods* (Addicot et al., 1987), defined by the upper (extent, object/scene size) and lower (grain, spatial resolution) limits of data information content and perception (Wiens, 1989) and cited literature).

The matching of various resolution levels of satellite sensor families with the organizational levels of biological systems and organism perception is one aspect – the correspondence with spatial and temporal domains of environmental policies another. Satellite Earth observation (EO) has started to become a ubiquitous means, a 'democratic tool' to observe what is happening on the different levels of political implementation (Lang et al., 2013a). The EU Habitats Directive (short HabDir, Council Directive 92/43/EEC), essential part of the European endeavour towards the CBD (Trochet and Schmeller, 2013), is an ambitious legal instrument to safeguard biodiversity and set aside a network of protected areas (Gruber et al., 2012), called *Natura 2000*, which currently comes to a completion (Evans, 2012). HabDir entails standardized and frequent (every six years) monitoring and reporting activities with specific responsibilities on all political levels of implementation, (1) the local management authorities for the monitoring of individual protected sites, (2) the EU member states for reporting on the status of the network of protected sites and habitats distribution over the entire territory, (3) the European Union for aggregating this information and the reporting towards the CBD. Updated geospatial information products are required at all three levels, not only by upscaling lower level information, but also to provide additional independent information on each level. In this framework, EO data and related techniques offer objective, yet economically priced solution to (1) provide timely information on pressures and impacts, (2) establish spatial priority for conservation, (3) collect long-term multi-scale baseline information for evaluating the effectiveness of conservation strategies (Fig. 1).

Habitats – Earth observable spatial entities

Habitats are fractal spatial entities of the biophysical environment whose definition depends on the scale at which they are considered (Blondel, 1979). In other words, habitats are physical expressions of biodiversity, covering a certain area with specific compositions and spatial features. The areal extent and the scaled appearance make them 'Earth observable' (Bunce et al., 2008; Kosmidou et al., 2014; Lang et al., 2013a). Habitats are not just observable in existence or extent, but also discernible in composition and alteration of internal conditions, e.g. (Bradley and Fleishman, 2008; Costanza et al., 2011). This also refers to shifts in the condition of that particular habitat corresponding to any grade of the hemeroby gradient that is considered, under current or future visions (Millar et al., 2007), as valuable for biodiversity conservation.

With recent advances in EO data availability and the forthcoming of powerful data analysis tools, we enter a new dimension of satellite-based information services in the domain of habitat and biodiversity mapping. Despite these achievements, we still

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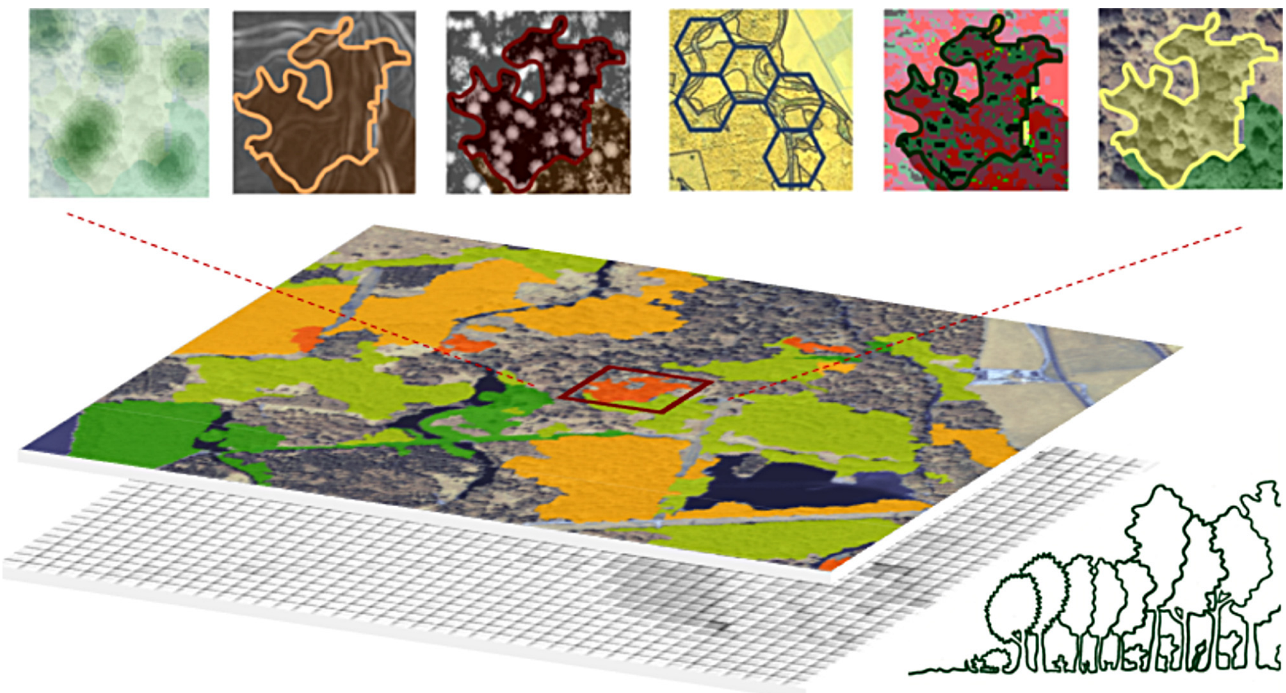

Fig. 1. Satellite Earth observation enables to map and monitor a variety of aspects on habitat distribution, quality and change in different spatial and temporal scales. *Source*: B. Riedler, S. Lang.

face scientific and methodological challenges in terms of e.g. data integration (satellite and in situ), advanced pre-processing and calibration, automated information extraction, ground verification and product validation, transition between mapping schemes and semantic interoperability, value adding with derived analytical products, visualization and web sharing. While great progress has been made in applying techniques on experimental, case-by-case level–see the review article by C. Corbane et al. in this issue (Corbane et al., 2014) – there are gaps to be filled in methodological robustness and transferability when moving towards a more operational level. Moreover, it has become even more apparent that habitat/landscape analysis using EO data and techniques is a cross-discipline task, requiring a greater conceptual and terminological harmonisation and actual cooperation between the 'remote sensing', the 'ecology' and the 'stakeholders' communities (Corbane et al., 2014; Nagendra et al., 2014).

From experimental research to operational solutions

Within the policy framework for EO-based biodiversity monitoring sketched above, we focus on some specific requirements related to the EU 2020 Biodiversity strategy (Commission 2011). By adopting the global Strategic Plan for Biodiversity 2011–2020 issued at the Tenth Conference of the Parties (CoP10), the EU 2020 biodiversity strategy has strengthened its implementing power as compared to the previous 2010 strategy (Lang et al., 2013a). A set of verifiable goals are listed, which are closely related to HabDir. By 2020, the strategy is to double the number of sites with a reported favourable status. HabDir fosters the conservation of natural habitats, fauna and flora in the European territory, and is complemented by the Birds Directive (2009/147/EC) a likewise ambitious legal instrument for nature conservation The physical expression of this policy framework is a coherent ecological network of 'sites of community interest' known as Natura 2000. The purpose of the network is to assure the long-term survival of Europe's most precious and threatened species and habitats across Europe. As mentioned above, HabDir has a strong monitoring and regular reporting component to oversee the success of its implementation and to gain pan-European information on the status of biodiversity. However, many member states are still lacking the ability to provide such information in a regular and routine fashion (Vanden Borre et al., 2011).

Two European Framework Programme (FP7) projects, MS.MONINA (www.ms-monina.eu) and BIO_SOS (www.biosos.eu), addressed these needs, by exploring the potential of EO data in combination with data from ground surveys for supporting management options and reporting of obligations.[1] The projects have prepared the ground for establishing services to support a successful implementation of HabDir on all levels (Blonda et al., 2012b; Lang et al., 2013b). Services, developed in a pre-operational mode, underlay four suitability criteria as identified by Vanden Borre 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 different image types; (3) user-friendly, allowing integration of the products into existing workflows; (4) cost-efficient, providing reliable and reproducible products at an affordable cost, compared to traditional field methods.

MS.MONINA – multi-scale service for monitoring Natura 2000 habitats of European community interest

MS.MONINA operates on interrelated user and scale levels for the successful implementation HabDir and the linked Natura 2000 concept. Several service components are offered, and each of the service developments follows the intervention logic of HabDir in three levels, tailored to the (user- and) technical requirements that are specific for each service level. Based on these specifications a testing, comparison and integration of state-of-the-art

[1] See White Paper on "Copernicus Biodiversity Monitoring Services" available at http://www.biosos.eu/publ/White_Paper_Biodiversity_Monitoring_BIOSOS_MSMONINA.pdf.