From Space to species: Solutions for biodiversity monitoring

by By Palma Blonda, Richard Lucas and João Pradinho Honrado – on behalf of *BIO_SOS* consortium

ACROSS A RANGE OF SCALES, NATURA 2000 SITES WHICH HAVE BEEN DESIGNATED FOR PROTECTING BIODIVERSITY AND ECOSYSTEMS ARE STILL THREATENED BY HUMAN ACTIVITIES, SUCH AS LOGGING, MINING, POACHING, AGRICULTURAL INTENSIFICATION, CONTAMINATION, INFRASTRUCTURE DEVELOPMENT FOR TOURISM AND SPILLAGE OF WASTES. WHILST SUCH EVENTS AND PROCESSES MAY OCCUR WITHIN THE BOUNDARY OF PROTECTED SITES, OFTEN THEY TAKE PLACE IN THE SURROUNDING LANDSCAPE AND PARTICULARLY WHERE URBAN AREAS AGRICULTURE OR TOURISTIC SITES ARE IN CLOSE PROXIMITY. THE CUMULATIVE EFFECT OF SUCH ACTIVITIES THROUGH TIME CAN EVENTUALLY LEAD TO HABITAT LOSS, DEGRADATION AND FRAGMENTATION. IN THE PAST, SUCH CHANGES HAVE RARELY BEEN MONITORED EFFECTIVELY OR ROUTINELY.

The recent provision of very high spatial resolution (< 4 m) remotely sensed data and automatic classification techniques has provided a unique opportunity for periodic and automated mapping of land surfaces and habitats and their changes over time. Whilst such monitoring may be undertaken externally, this capability will benefit local and regional authorities by providing timely information on pressures and impacts, allowing them to take appropriate action. The data and techniques will also contribute to national and international reporting requirements.

What was the need from end users?

In the European Union (EU), the Habitats Directive (92/43/EEC) and the Birds Directive (79/409/EEC) oblige Member States to report on the conservation status of species and habitats of European importance every six years and trends in status during the intervening period. However, as reported by the European Topic Centre on Biodiversity, data on species and especially habitats are collected in different ways, are unavailable, or are insufficient in their spatial coverage. For these reasons, the development of a uniform observation system that can be easily used by all Member States for reporting obligations and defining management strategies (either strategic or operational) is very important. This is particularly the case in Mediterranean countries, which typically lack long-term baseline data for assessing changes and evaluating biodiversity indicator trends. This is because there are few volunteer groups for observing biodiversity on the ground and the staff of nature protection agencies is relatively small and often not well equipped for the tasks they have to do.

"Innovative planning activity at a local level must try to modify a static municipal planning system into a dynamic planning system"

User requirements are varied but common requirements are as follows:

- Long-term baseline data (e.g., thematic maps at 1:5,000 scale or finer) of land covers types and habitats as well as new automatic, standardised, rapid and cost-effective monitoring techniques. These are needed to meet commitments, define management policies and assess the impacts of existing policy;
- A means of reducing costs, mainly related to in-field campaigns;
- Methods for assessing the significance of measured land cover changes and evaluating trends;
- Modelling techniques for evaluating the combined impact that different drivers affecting soils and/or vegetation may have on biodiversity over time.

Habitat maps, which are at the base of biodiversity indicators extraction, can be obtained by interpreting land cover maps of sufficient detail, with these often generated with EO-derived products and ancillary data. The *BIO_SOS* classification system has adopted the Food and Agriculture (FAO) Land Cover Classification System (LCCS) scheme and taxonomy for class identification because of its more generic approach. The scheme is also more suitable than CORINE as the land cover categories can be more readily translated to habitat categories, which better describe (semi)-natural systems (Tomaselli et al. 2012). Once mapped, a key component is to translate the land cover classes to habitat categories, as these are often needed for conservation efforts.
The use of General Habitat Categories (GHCs) was highlighted as a means of consistently and efficiently defining habitats in the previous *BioHab* and *Ebone* projects (Bunce et al., 2008, 2011). GHCs were proposed as they provided an exhaustive typology of habitat types that can be found in any terrestrial landscape around the globe, from natural ecosystems to urban areas, and from sparsely vegetated areas to multi-layered tropical forests (Bunce et al. 2011). GHCs also hold a close relation to other habitat classifications and particularly the Habitats Directive Annex I classification, which is of central importance for international reporting and Natura 2000 management (Bunce et al. 2012). Finally, as they describe landscapes in terms of habitat mosaics, the GHC mapping and recording methodology was also effective in describing and predicting the distribution of species and biodiversity, thereby contributing to the assessment of international sets of indicators while at the same time supporting the local management of endangered species and priority habitats.

Once generated, these maps can be updated over time to detect change, thereby supporting management options (either strategic or operational) and reporting of obligations under the Habitat Directive for management of Natura 2000 sites.

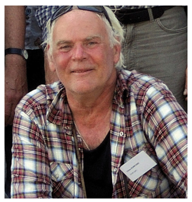
Figure 1. BIO_SOS Consortium: field visit of the Dutch site. The article is dedicated to the great scientist and friend to BIO_SOS *colleagues, Professor Maria Petrou, who is pictured above during an early visit to the* BIO_SOS *site in the Netherlands but was lost to cancer in October 2012 (Credits: Sander Mucher, Alterra).*

USER TESTIMONIES

Modelling techniques for providing scientific evidence as the basis of conservation policies and sustainable planning activities are required by end users, such as Regional Planning authorities.

"When regional authorities elaborate and approve a plan for a protected area, a buffer zone needs to be defined around the protected area where rules different from the ones to be adopted within the site have to be identified, discussed and approved. So far, we do not have any scientific evidence of the impact of different levels of protection rules (policies) within the areas and generally we use an a priori buffer area ranging from 100 m. to 5 km. When we enter into negotiation with local authorities and local people, we need to support our decisions with scientific evidence of the impacts that such rules may have on the areas and the importance of the buffer zone with restriction rules. For this reason we are interested in GMES products resulting from the BIO_SOS project. In addition, innovative planning activity at a local level must try to modify a static municipal planning system into a dynamic planning system. So we need indicators that can provide dynamic monitoring of the different planning processes and an evaluation of the effectiveness of the policies implemented."

Prof. Angela BARBANENTE,
Member of Regional Council for Environmental Quality,
and Protected areas, Regione Puglia-Italy.



Clive HURFORD from the Countryside Council for Wales (CCW) has been working with the BIO_SOS project on the development of the methods for mapping land cover types and habitat procedures, with particular focus on Cors Fochno in Wales.
"CCW is investing in new technologies for monitoring protected sites, and particularly across the NATURA 2000 network in Wales. All of our sites are experiencing changes, with causes ranging from habitat succession, human disturbances and natural events such as flooding, and we need to quantify and understand the impacts of these changes. We also need to monitor how our management actions are affecting the extent and condition of the threatened NATURA 2000 habitats and their associated species, not only within our reserve network but also in surrounding areas. The BIO_SOS project at the Cors Fochno test site in Wales has given us an insight into how Earth Observation data can be used to support our field monitoring and this has motivated us to acquire very high spatial resolution satellite and supporting image data collected by Unmanned Airborne Systems (UAS) at other NATURA 2000 sites. Given the rapidity of the changes that can occur over quite large areas, we need to use remote data more proactively in our monitoring to help deliver our obligations for national and international reporting. BIO_SOS has been instrumental in informing our approach to this monitoring."

In this framework, the *BIO_SOS* project is providing local and regional authorities the following services.

- Very detailed land cover/use maps, based on the integrated analysis of (as a minimum) two high or mainly very high spatial resolution satellite images acquired in two different seasons corresponding to the peak of vegetation flush and the period before or after;
- General Habitat Categories (GHCs) and Annex 1 Habitat maps derived from land cover/use maps, based on a set of expert knowledge rules and ancillary data[1]. The set of rules can also be applied to pre-existing validated land cover/use maps or to historical satellite images;
- Land cover/use and habitat change maps obtained by comparing maps from different years.

In addition, the project is also providing:

- Biodiversity indicators from remotely sensed data;
- Biodiversity indicator trends for biodiversity pressure scenarios through indicators evolution over time.

As an example, the *BIO_SOS* project in Wales has been focusing primarily on the NATURA 2000 site of Cors Fochno, which contains the Annex I habitats of an active and modified raised bog in an estuarine environment, which also includes saltmarshes and sand dune complexes.
For this site, a time-series of very high spatial resolution Worldview-2 data has been obtained covering the period prior to the spring flush of vegetation (in March), the peak flush (July) and the senescent period (November). From these

[1] In digital image processing, data from sources other than remote sensing, used to assist in analysis and classification or to populate metadata (source: www.esri.com).

BIO_SOS in a nutshell (www.biosos.eu)

BIO_SOS *has made progress towards developing an operational system for effective and timely monitoring of NATURA 2000 sites and their surroundings*. Based on the expert knowledge of botanists, ecologists and end local site managers, *BIO_SOS* is developing a classification system that is able to integrate remotely sensed data from a satellite sensor and ground reference data. Land cover / use and habitat classes are described by the experts in terms of their temporal characteristics and / or spatial relationships and this information is used in the classification. For example broadleaved and coniferous forests, are discriminated based on seasonal differences in reflectance as a function of leaf cover and type whilst sand dunes may be separated from other bare areas because of their close proximity or adjacency to the coast line. Once land cover classes and habitats are described through a semantic language, any site can theoretically be mapped and subsequently monitored over time. Where it is difficult to provide expert rules for describing classes of interest, specific ground data can be collected but this is only necessary in specific *attentive (homogenous)* areas identified by remote sensed data segmentation, with these resulting in a reduced requirement for *in situ* campaigns (e.g., vegetation inventory). *BIO_SOS* is also focusing on the development of a modelling framework for pressure analysis and threat assessment in different protected areas (Mairota et al., 2012, Harini at al. 2012) with the aim to evaluate their impacts on habitats.

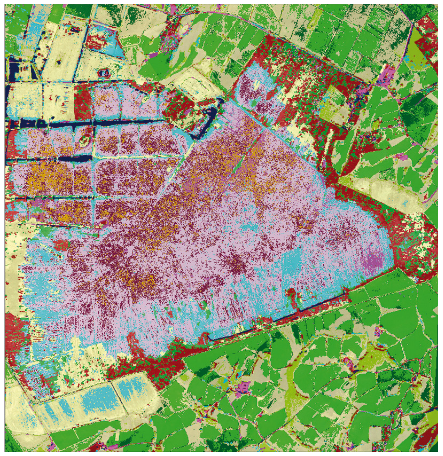


Figure 2. Classification of General Habitat Categories (GHCs), Cors Fochno (UK0014791 SCI/SPA), Wales generated using time-series of Worldview-2 data from Aberystwyth University. The classification within the active and modified raised bog (centre) is at 2 m spatial resolution and reflects the complexity of plant species that comprise the bog surface (Credits: Aberystwyth University).

data, as well as others at European sites, we have been able to develop the use of the FAO LCCS for land cover classification. The method uses a combination of spectral and contextual rules that follow the LCCS scheme and can ultimately be applied at any location regardless the satellite data used. Through *BIO_SOS*, we have then developed methods for translating the LCCS land cover categories in Wales to a habitat category, using the framework of the GHCs. We then describe these habitats in more detail, particularly where these are complex as in the case of the active bog. The maps of habitats generated (Figure 2) are providing the most detailed for the NATURA 2000 site and surrounds. Furthermore, additional image acquisitions are being obtained to establish approaches for the detection of change, including where these impact on the long-term conservation status of the site.

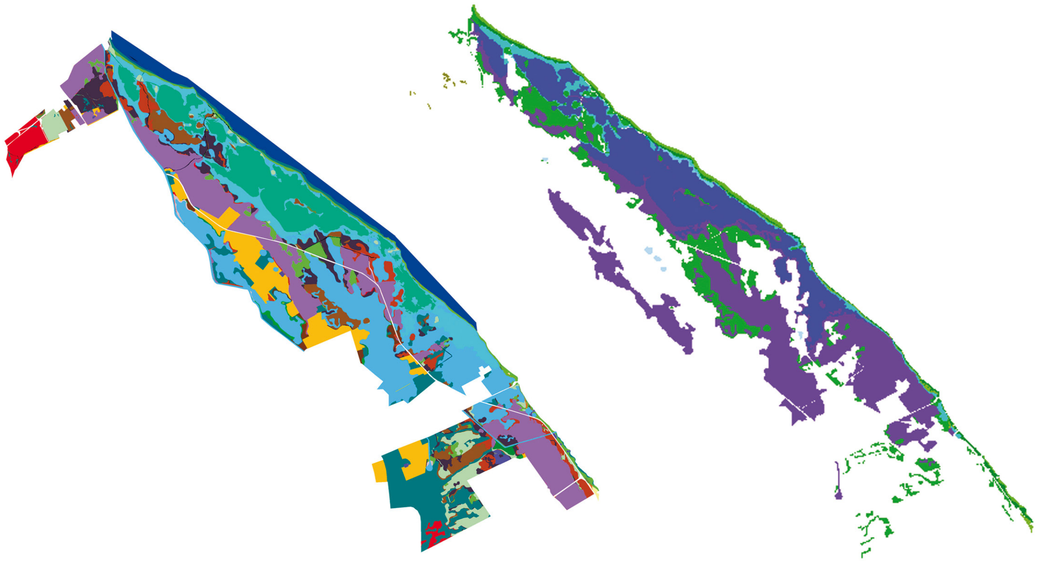
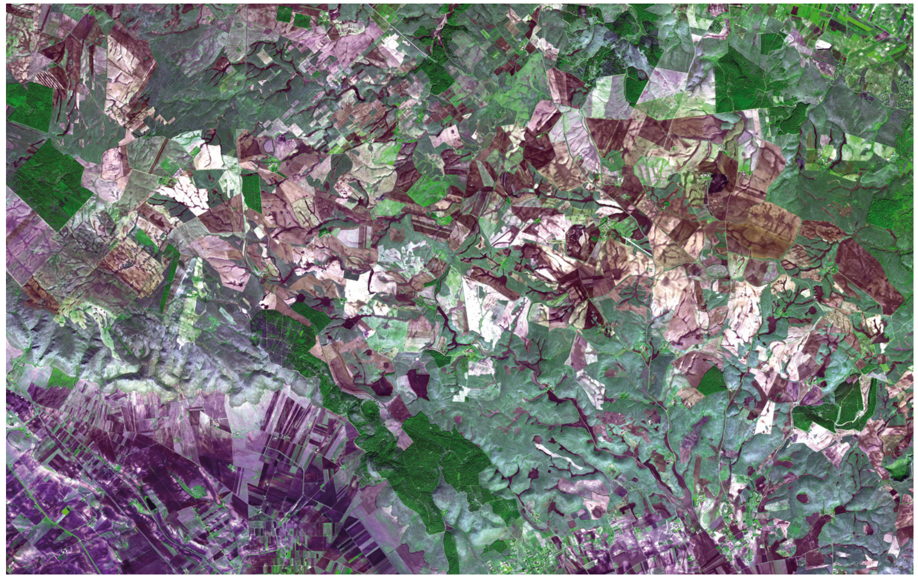


Figure 3. Habitat maps for Le Cesine site (IT9150032 SCI/SPA): Left map: General Habitat Categories (GHC) Cesine site. The colours correspond to different habitats in the GHC taxonomy. Yellow represents cultivated areas with olive grove; Light blue corresponds to Herbaceous Wetland Emergent Hydrophytes; dark blue is the sea. Right map: Annex 1 habitats. The colours represent Annex I habitats, e.g light blue corresponds to coastal lagoons (Credits: CNR-ISSIA).



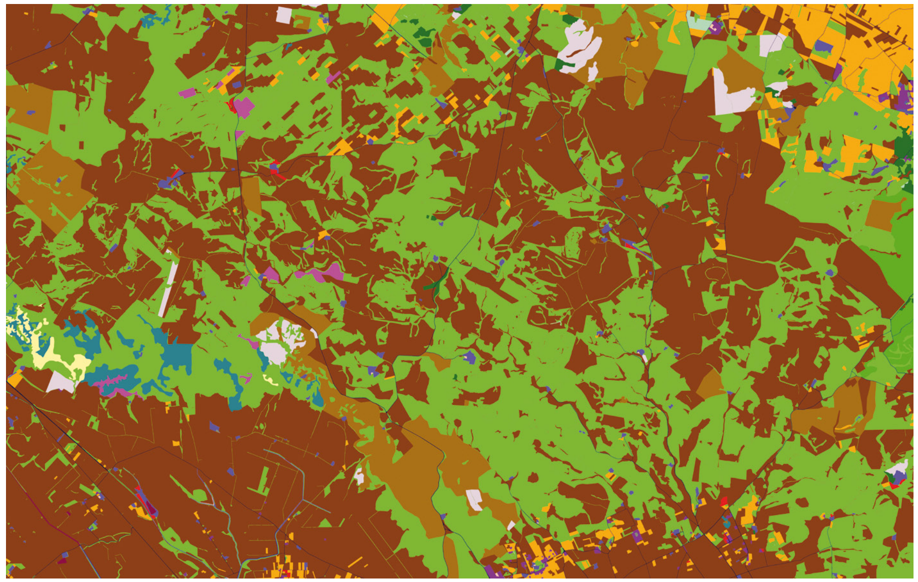


Figure 4. Murgia Alta Natura 2000 site (IT9120007 SCI/SPA). Original Worldview2 image and GHC map. In this site Grassland ecosystems were considered as focal habitat types. Substantial losses of this ecosystem have occurred between 1990 and 2000 mainly due to EU incentives promoting durum wheat production, contemporaneous to the enforcement of the 92/43/EEC Directive (Mairota et. al 2012) The colours in the low map represent different GHCs. Some examples: light green corresponds to Herbaceous Leafy Hemicryptophytes, brown colour represents Phanerophytes Evergreen Coniferous Trees, very dark green is for Broadleaved Deciduous Trees. (Credits: CNR-ISSIA).

In the Mediterranean, our studies have focused on generating GHC and Annex 1 habitat maps for NATURA 2000 sites at Le Cesine (Figure 3) and Murgia Alta in Italy. Additional study areas are located in Portugal, Greece and the

Netherlands. To demonstrate more general use, the methods are also being developed in two highly biodiverse tropical countries, Brazil and India.

"The use of General Habitat Categories (GHCs) supports the local management of endangered species and priority habitats"

GMES products for Biodiversity monitoring (examples from different sites including land cover and GHC habitats)

In this framework, very high resolution Earth Observation data are very useful for biodiversity inventories and monitoring for adaptive management on a regional and local scale since they can provide/extract information similar to field samplings, thereby reducing the need for extensive, expensive and time intensive field surveys, as well as decreasing the time interval between updates. These data thus provide the opportunity for more rapid and effective management responses to changes and threats (Nagendra et al., 2012).

The expert knowledge classification approach adopted by *BIO_SOS* strongly involves end users, including those from the scientific community (e.g., botanist, ecologists) and local managers. The method allows the description of a specific habitat to be generalised such that these can be automatically identified when different sites and conditions are encountered. Consequently, the products proposed by *BIO_SOS*, such as habitat maps and biodiversity indicators, will be more familiar to the End Users since they are built on their expertise and can be improved as they further engage with the process.

BIO_SOS will strongly support reporting for the Convention of Biological Diversity (CBD), the European Biodiversity Strategy and the Habitat Directive by making the information directly compatible and so will become central to the whole process of managing biodiversity in Europe. By integrating *in situ* data with reliable global land observations based on Earth Observation, *BIO_SOS* will allow us to unravel certain patterns and processes that were formerly not well understood. This information can then be used to adjust or fine-tune existing conservation objectives, especially in the Mediterranean areas. Moreover, *BIO_SOS* proposes an ecological modelling system that can offer an important tool to monitor changes in the distribution and status of ecosystems within and along the borders of protected areas.

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