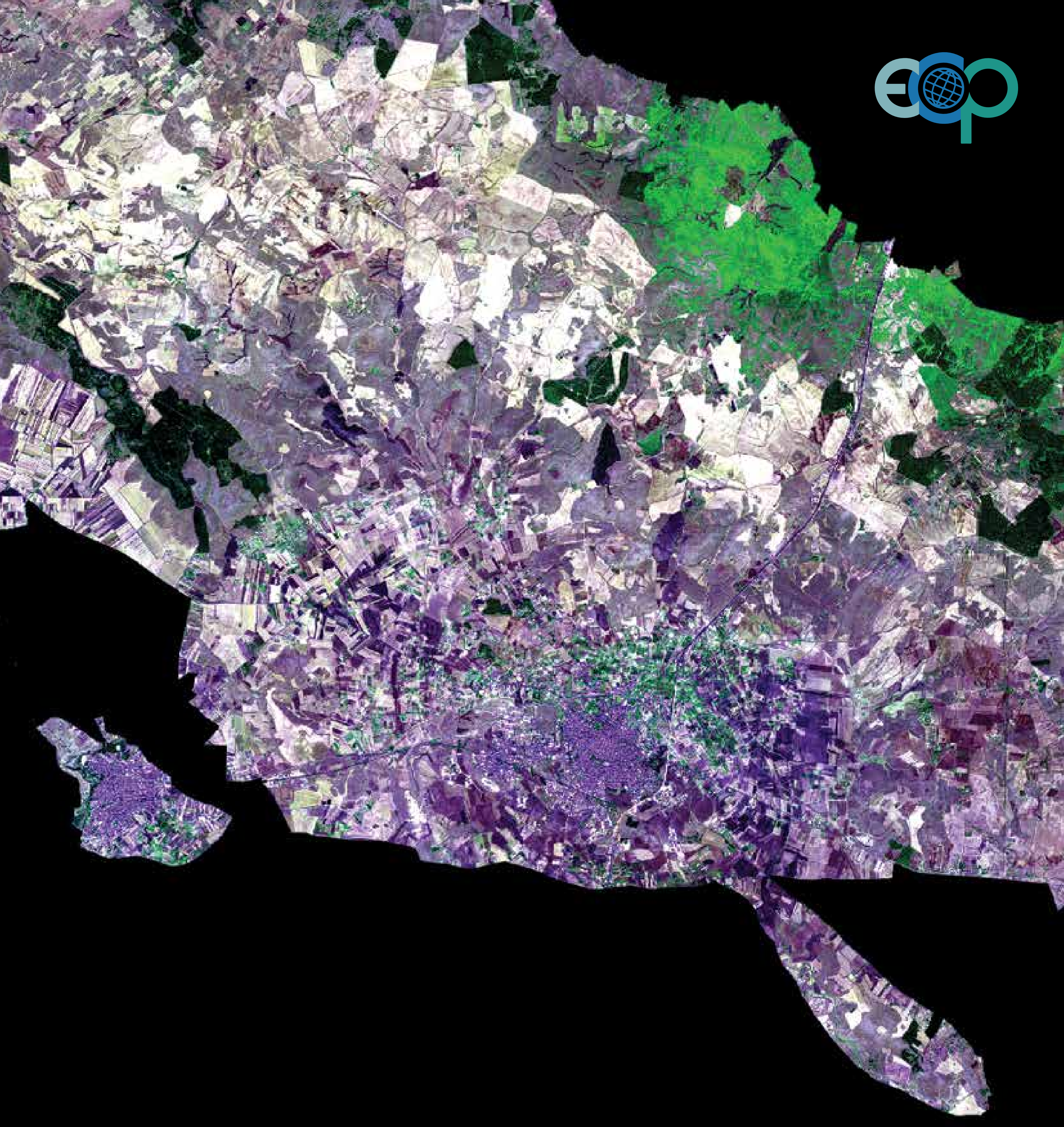
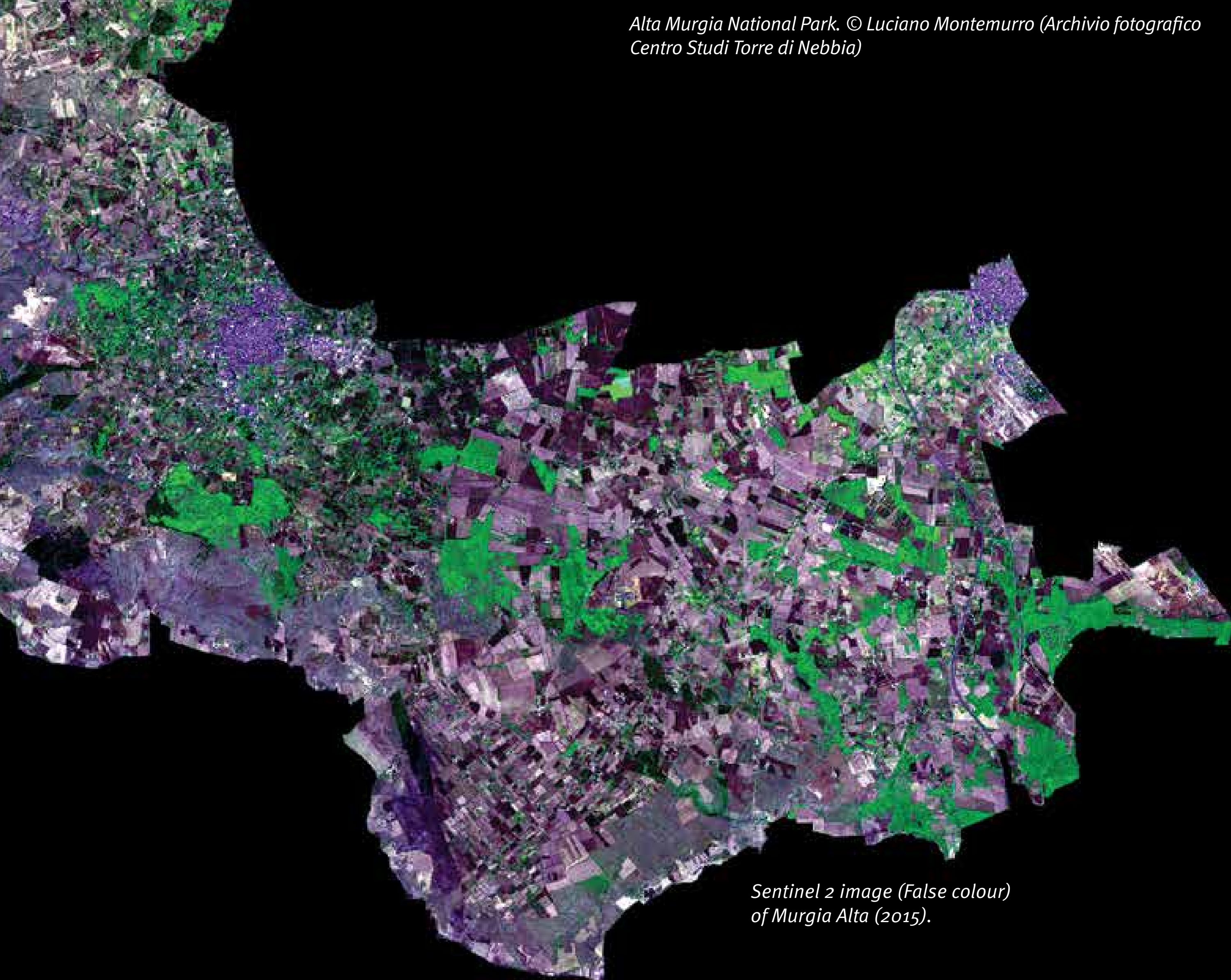


Earth Observation for Environmental Management

**Science for post 2020 Environmental targets:
Insights from Earth Observation of Protected Areas**

This background document was presented at the Science-Policy Brief meeting “Science for post 2020 Environmental targets: Insights from Earth Observation of Protected Areas” at the European Parliament, Brussels on 27 September 2018. The event was co-organised by ECOPOTENTIAL, IUCN and UNEP-WCMC. This document represents the view of the ECOPOTENTIAL project on the use of Earth Observations for improving nature conservation policies.

Alta Murgia National Park. © Luciano Montemurro (Archivio fotografico Centro Studi Torre di Nebbia)



Sentinel 2 image (False colour) of Murgia Alta (2015).

Introduction

Ecosystems provide essential goods and services to human society. Ecosystem services are those benefits that ecosystems provide to humans, such as clean air and water, raw materials, food, recreation and cultural values. Protected Areas, such as UNESCO Natural Heritage sites and national parks, often include critical, diverse and endangered ecosystems and play a central role for conservation in our rapidly changing environment. They also provide treasures of long-term ecological, environmental, climatic and socio-economic data, and support continuous field monitoring.

In the last decades, however, human pressures such as climate and land-use change, invasive species and pollution are threatening ecosystem integrity, potentially leading to loss of crucial ecosystem processes, functions and services. Knowledge-based conservation and management policies are necessary to preserve and improve the benefits that healthy ecosystems provide for our well-being.

Peneda-Gerês National Park. © Luis Borges/ADERE/Peneda-Gerês

Valuing natural ecosystems through the services they provide to humankind is one way to estimate the natural capital and to provide relevant conservation and management policy indications. However, the value of ecosystems should not be based only on economic estimates and it should also include other aspects such as landscape and ecosystem integrity and functionality, biodiversity conservation per se, cultural and spiritual values. This endeavour requires effective monitoring and understanding of ecosystem conditions, processes, dynamics and changes, fully accounting for the wide spectrum of interactions between society, geosphere, biosphere and climate.

Earth Observation (which includes field measurements) and Remote Sensing (for example, observations with drones, planes and satellites, such as the new EU Sentinel satellites) contribute substantial opportunities for science and policy. This Policy Brief highlights findings of the Horizon 2020 ECOPOTENTIAL project, which supports the use of Earth Observation in Protected Areas across Europe and beyond, and it offers perspectives on future ecosystem and biodiversity frameworks and targets. Protected Area managers and environmental scientists are connected through the development and application of reliable and practical indicators and the science-policy interface should facilitate the two-way flow between information need and information supply.

Remote Sensing retrieves information without being in direct physical contact with the object under study, such as for data collected from drones, planes and satellites

In-situ measurements refer to data collected in the field by local devices such as thermometers, rain gauges, or biodiversity samplings

Earth Observation includes both Remote Sensing and in-situ measurements

New, big data on our environment are yet to be fully integrated in environmental management. Numerous opportunities exist, such as displaying Earth Observations in freely accessible online platforms, one important step for integration of data into decision making, such as pursued by the EU Copernicus programme. An additional challenge is the full exploitation of existing infrastructures such as LifeWatch ERIC and the related technical capacity to analyse and make best use of abundant Earth Observation data, something that ECOPOTENTIAL is addressing and that can be improved in future policy. Earth Observation is in fact relevant for implementing a range of EU environmental strategies, for example, the EU Biodiversity Strategy, which aims to halt the loss of biodiversity.

Earth Observation of ecosystems

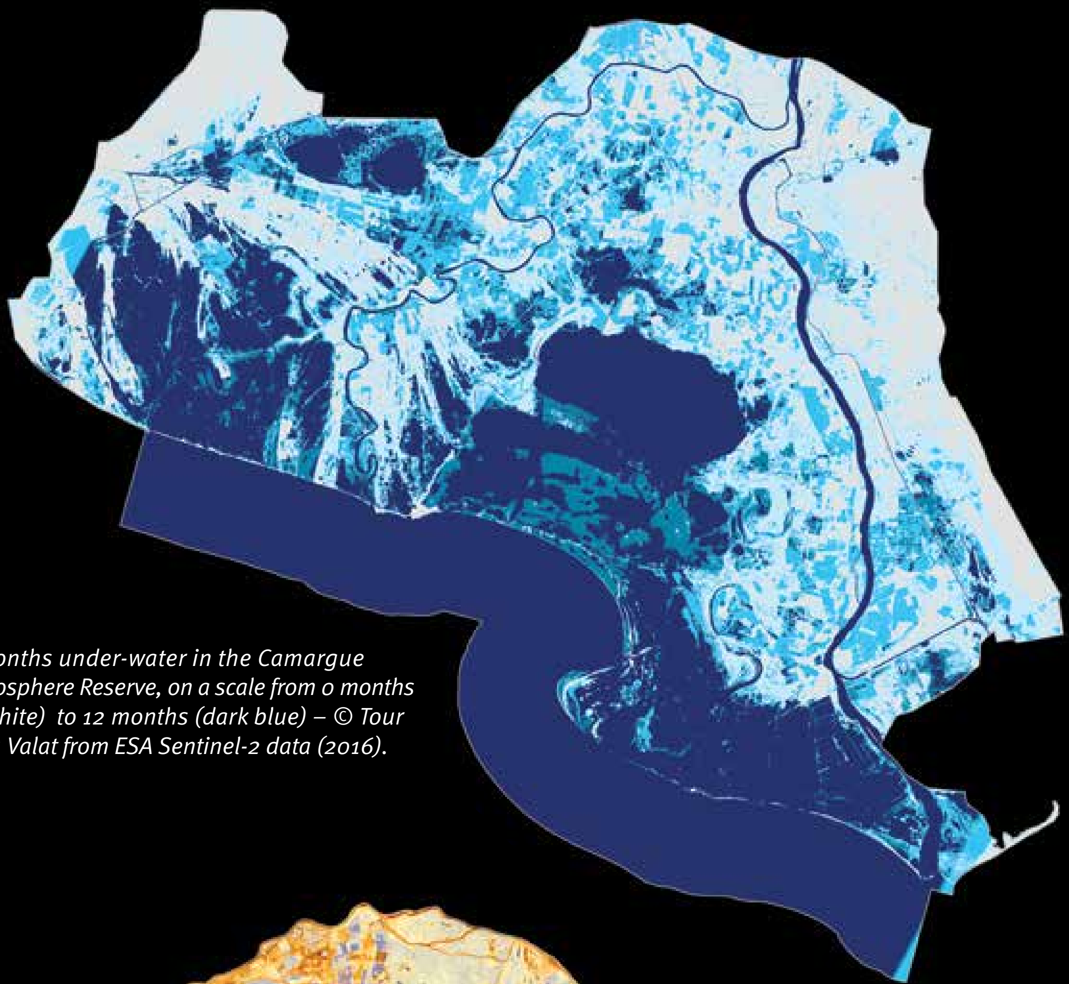
New satellites, field measurements and scientific developments are opening vast opportunities for improved monitoring and understanding of nature, as already showcased in other documents such as the *"Future Brief: Earth Observation's Potential for the EU Environment"*, released in February 2013). This event updates the situation five year later, with a more focussed lens on biodiversity and ecosystem functions and services.

Great white pelican (Pelecanus onocrotalus) in the Danube Delta. © iStock/CalinStan

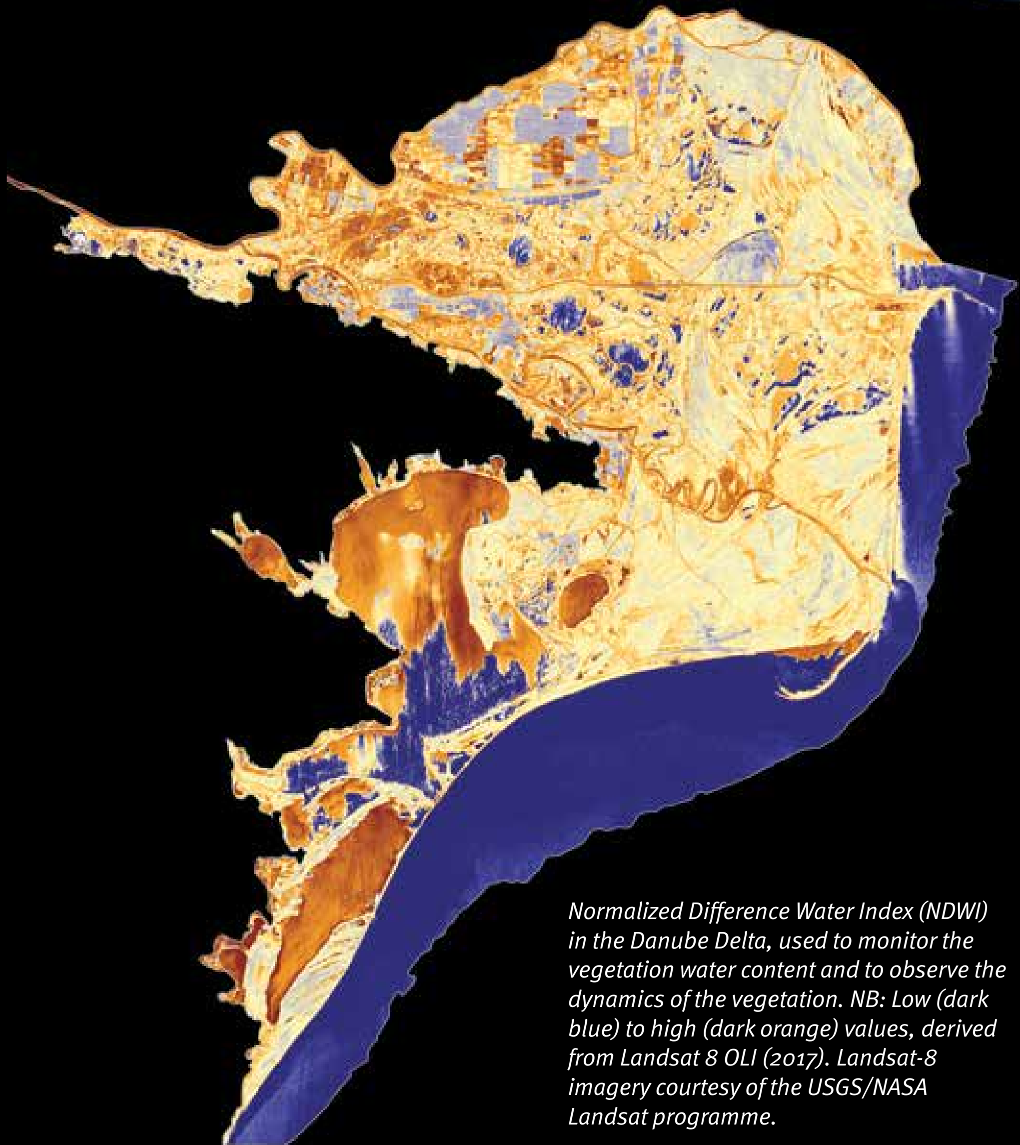
Remote Sensing provides consistent and plentiful data about the environment, not possible with traditional, resource intensive field measurements. On the other side, ground measurements are necessary for monitoring the many variables that currently cannot be measured from space, as well as for validating Remote Sensing results. In Europe and globally, Remote Sensing generates substantial data and usable products with wide applications to the environment, urban development, safety and health.

The European Space Agency (ESA) budget for 2018 was about €5.6 billion of which the Earth Observation domain comprise 26% or €1.4 billion. The Copernicus Programme has cost the European Space Agency (ESA) about €7 billion since 2002. Much effort is now needed to promote the use of Earth Observation tools for practical environmental management.

The Camargue. © J.Jalbert-Tour du Valat



Months under-water in the Camargue Biosphere Reserve, on a scale from 0 months (white) to 12 months (dark blue) – © Tour du Valat from ESA Sentinel-2 data (2016).



Normalized Difference Water Index (NDWI) in the Danube Delta, used to monitor the vegetation water content and to observe the dynamics of the vegetation. NB: Low (dark blue) to high (dark orange) values, derived from Landsat 8 OLI (2017). Landsat-8 imagery courtesy of the USGS/NASA Landsat programme.

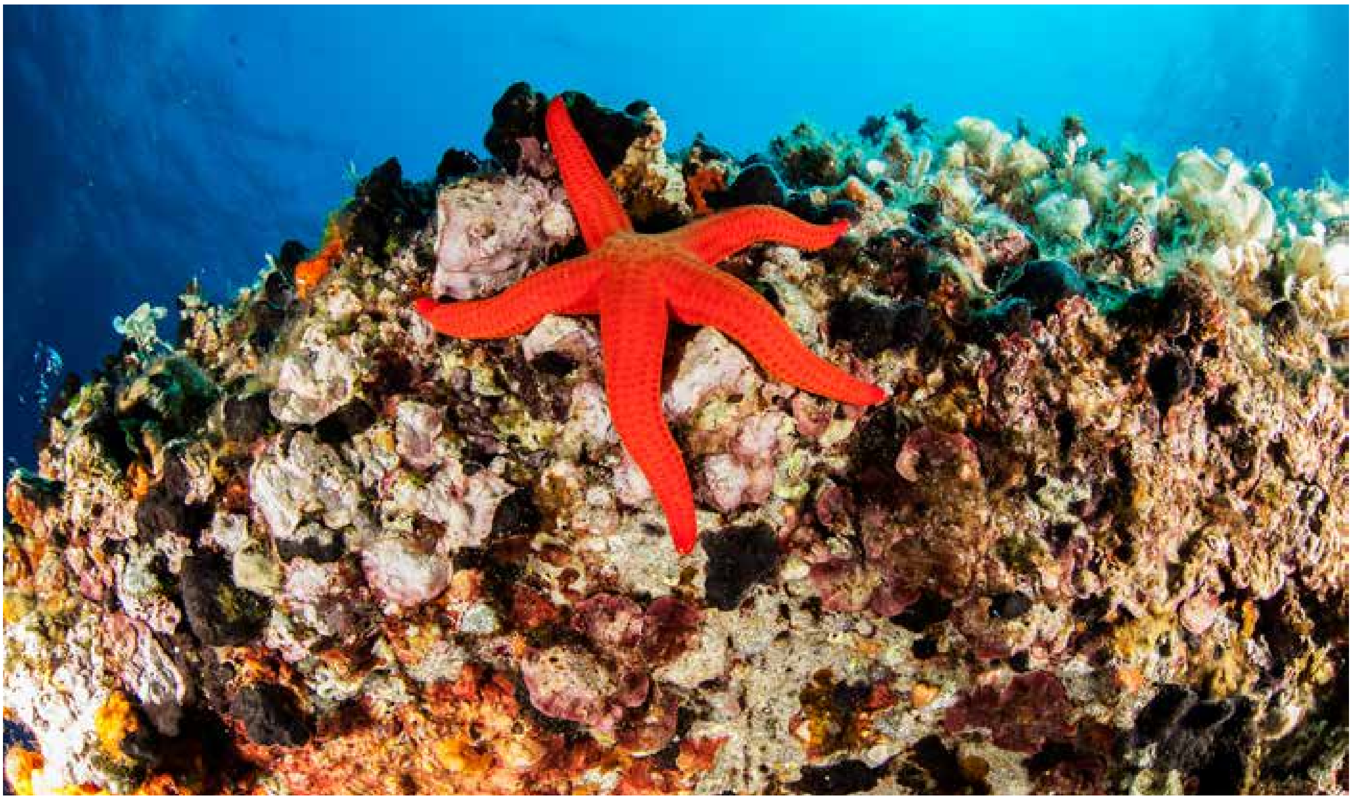
Earth Observation and ecosystem policy relevance

Existing Policies

The Biodiversity Strategy 2020 addresses ecosystem services, e.g., with the Mapping and Assessment of Ecosystems and their Services (MAES), but it does not mention Remote Sensing (or Earth Observation) explicitly. Other directives such as the Birds Directive, Habitat Directive, and Regulation on Invasive Alien Species, do not mention Remote Sensing or ecosystem services. Instead, the Natura 2000 network, of which the Birds and Habitat Directives are a part, links to ecosystem services. In the marine realm, the Marine Strategy Framework Directive is the first to explicitly mention ecosystem services but does not address Remote Sensing or Earth Observation (preamble 8). The State of Europe's Seas report demonstrates a methodology to derive ecosystem services state based on information from assessment reporting under the Marine Strategy Framework Directive. Clearly, the potential exists for making full use of an integrated, not purely economic view of ecosystem services and of the quantitative data provided by Earth Observation, to improve and refine nature management and conservation policies as well as sustainable development strategies.

Key ECOPOTENTIAL Policy-Relevant Findings

Based on the progress and results of ECOPOTENTIAL to date, a selection of policy-relevant findings is presented, including those extracted from a synthesis study, based on questionnaires and interviews with Protected Area staff and designed to identify the main challenges and needs in conservation and management of Protected Areas. In particular, we investigated whether and how Remote Sensing and the concepts associated with ecosystem integrity and services are of any relevance (and are used) for Protected Area management. The answers revealed that knowledge and appreciation of Remote Sensing was quite widespread but generally considered technically challenging, with most Protected Areas staff asking for further training in the practical use of Remote Sensing products, and also highlighting the need of development and support of innovative methods for field (in-situ) measurements. On the other hand, the use of an ecosystem services framework by Protected Area managers was not common and sometimes considered scarcely useful for the practical conservation issues that Protected Areas have to face in daily management.



Mediterranean red seastar. © Dimitris Poursanidis/FORTH

The ECOPOTENTIAL Project

ECOPOTENTIAL, a large, European-funded H2020 project, focuses on a targeted set of internationally recognised Protected Areas in Europe, European Territories and beyond, including mountainous, arid and semi-arid, and coastal and marine ecosystems. Building on knowledge gained in individual Protected Areas, the ECOPOTENTIAL project addresses cross-scale ecological interactions and landscape-ecosystem dynamics at regional to continental scales, as well as long-term and large-scale environmental and ecological challenges.

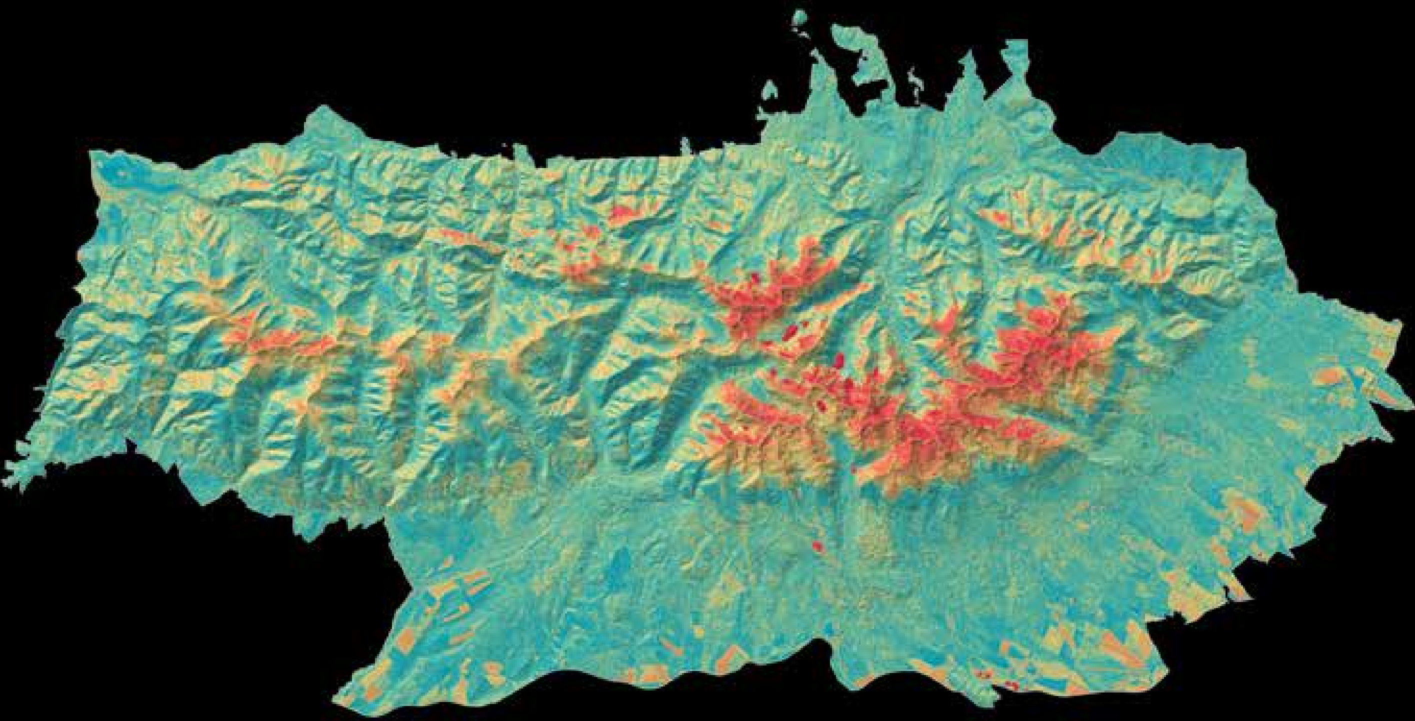
ECOPOTENTIAL considers the entire chain of ecosystem services, by developing and using field and Remote Sensing data (including from the Copernicus programme), modelling current and future ecosystems, and estimating current and future ecosystem services and benefits. The focus is on quantifying the changes in ecosystems and biodiversity, and developing site-specific questions and approaches, co-designed with the Protected Area staff in order to address park management issues.

www.ecopotential-project.eu

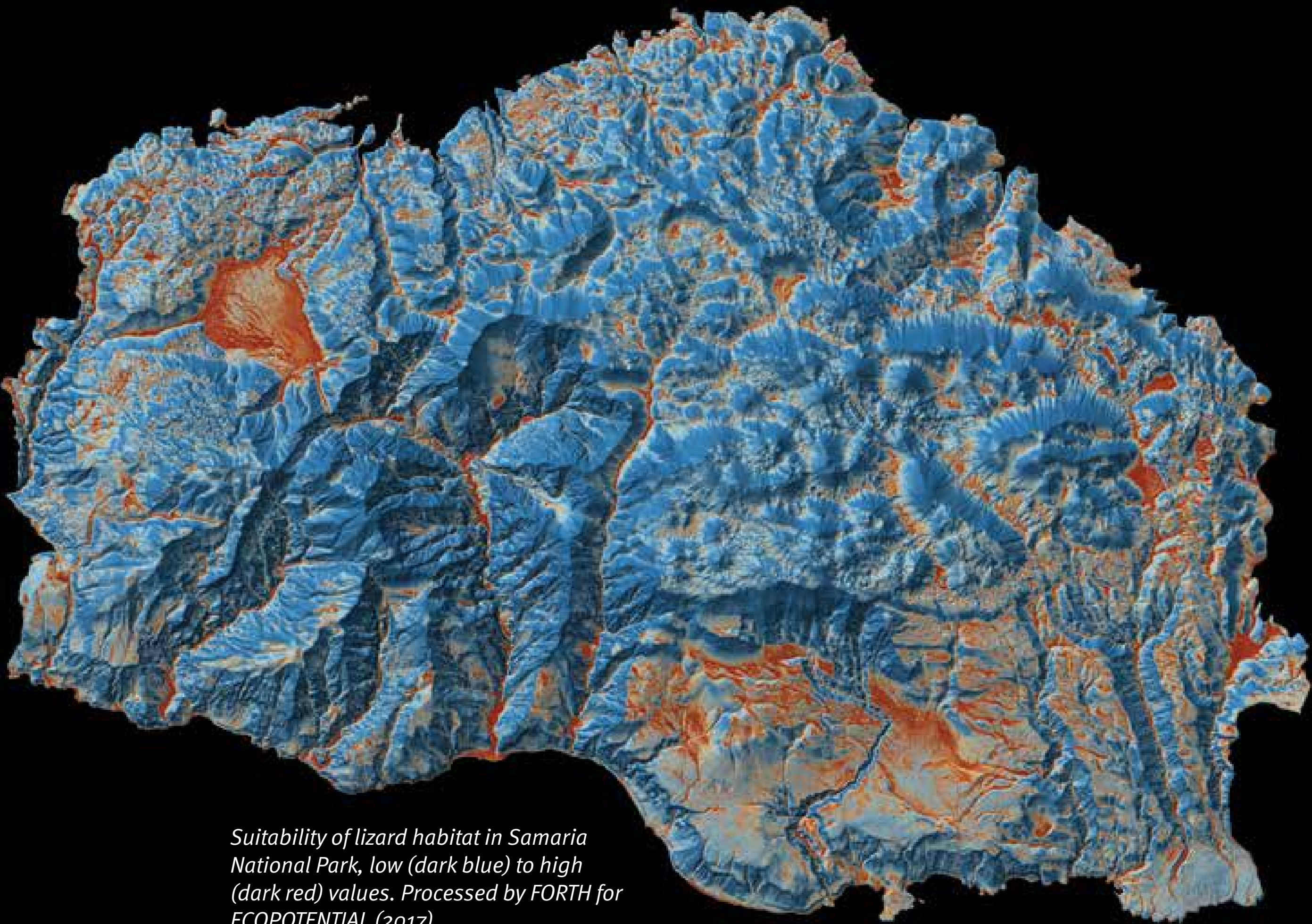
An important finding was that many Protected Area managers feel that the concept of ecosystem services is not always compatible with the needs of conservation, and that sometimes global frameworks are imposed in a top-down fashion without discussing the practical issues to be addressed. This clearly calls for a deeper involvement of technical and management staff working in the field in the definition of large-scale policies, as well as for creating frameworks (in this case, ecosystem services) that better represent the reality and complexity of European ecosystems.

To at least partially respond to these requests, in ECOPOTENTIAL a set of specific research activities were co-designed with the staff of the Protected Areas involved in the project, to tackle concrete and immediate management issues starting from the identification and critical analysis of ecosystem services and functions, biodiversity and the use of Earth Observation. The Annex with case studies reports detailed examples of the use of Earth Observation in the project's Protected Areas.

Lapporten, Abisko National Park.© Scott Wilson



Vegetation cover in the Tatra Mountains, scaled from none (dark red) to high (dark green). Levi Westerveld (GRID-Arendal) from ESA remote sensing data (Sentinel 2, 2017).



Suitability of lizard habitat in Samaria National Park, low (dark blue) to high (dark red) values. Processed by FORTH for ECOPOTENTIAL (2017).

Distribution of the natural hydrological network in Sierra Nevada (blue) in comparison with the network of ancient irrigation channels (orange). The background image shows photosyntetically active vegetation (green), bare soil and snow (both light coloured). USGS/NASA Landsat 5 TM 2011-06-19. Irrigation channel data courtesy of EU F7 MEMOLA project.

Recommendations

Expand the use of Earth Observation to monitor and manage ecosystem services

Earth Observation, both Remote Sensing and in-situ measurements, offers great potential to monitor and manage ecosystem services in equitable and sustainable ways. The critical examination of the meaning and use of ecosystem services, the definition of easily measured and understandable relevant variables, and the use of Earth Observation to quantify ecosystem properties, functions and services are important steps to improve sustainable management of natural ecosystems and nature conservation.

Invest in the integration of Remote Sensing and in-situ measurements

Many biologically-relevant variables cannot be measured remotely and require in-situ measurements. Most biodiversity indicators fall in this category, as well as soil-atmosphere fluxes and soil structure. It is thus of primary importance to design integrated monitoring activities, able to extract information from both Remote Sensing data and the wealth of existing and new field data, developing and supporting innovative and extended in-situ measurement networks, such as the eLTER RI, and virtual laboratory networks for data analysis and interpretation, such as the LifeWatch ERIC.

Incorporate Remote Sensing indicators in future environmental strategies

Remote Sensing is now mainstream in science, is reliable and has proven value and application. It can, therefore, be integrated into indicator development, identification of policy targets and definition of future strategies. Its utility and application should only increase in time with improving technology and data time series. Including Remote Sensing in indicators can also make reporting simpler, more accurate and comparable across Europe. Additionally, if managers and users feel that there is direct relevance in EU strategies, this might enable better alignment and more understanding and awareness of policies and policy impacts which might increase the uptake of EU strategies. ECOPOTENTIAL successes and impacts, notably in the site-specific research questions and in the pan-European analysis of ecosystem changes, demonstrate some of the benefits deriving from the quantitative use of Remote Sensing of natural ecosystems.

Samaria National Park. © Dimitris Poursanidis/FORTH

Support innovative ideas alongside proven mechanisms of impact and scientific advancement

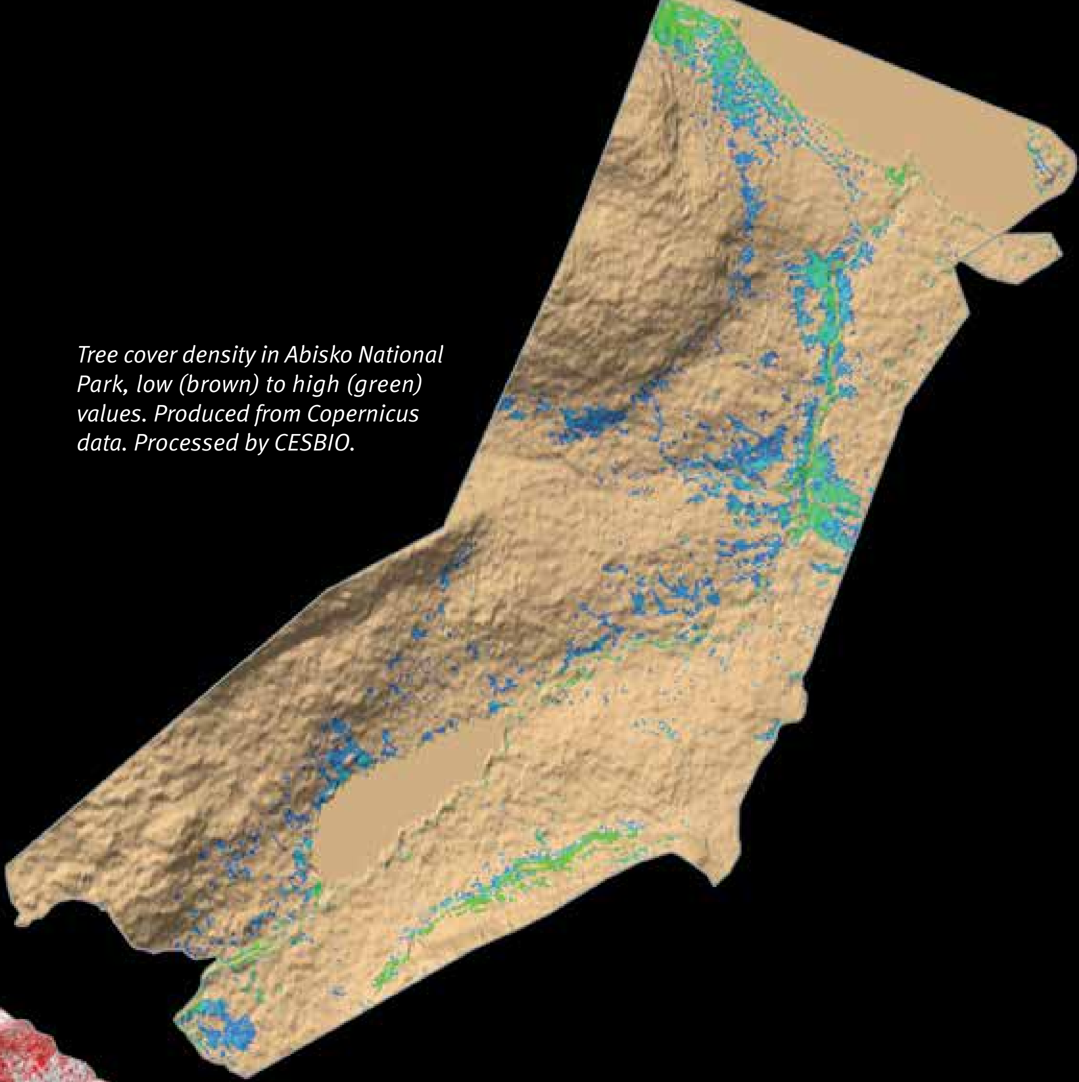
To stay at the forefront of impact and to achieve policy targets by means of improved knowledge, working on advancement innovative Earth Observation analysis methodologies is needed. Especially important is the definition of relevant variables and indicators (including, for example, Essential Variables) that can be measured by Remote Sensing and have the power to transform how we manage the environment. As an example, an ECOPOTENTIAL paper was recently published on the predictive ability of MODIS satellite-derived Ecosystem Functional Attributes (EFAs) as Essential Biodiversity Variables (EBVs), against traditional datasets (climate and land-cover) at several scales.*

*Arenas-Castro S, Gonçalves J, Alves P, Alcaraz-Segura D, Honrado JP (2018) Assessing the multi-scale predictive ability of ecosystem functional attributes for species distribution modelling. PLoS ONE 13(6): e0199292. https://doi.org/10.1371/journal.pone.0199292

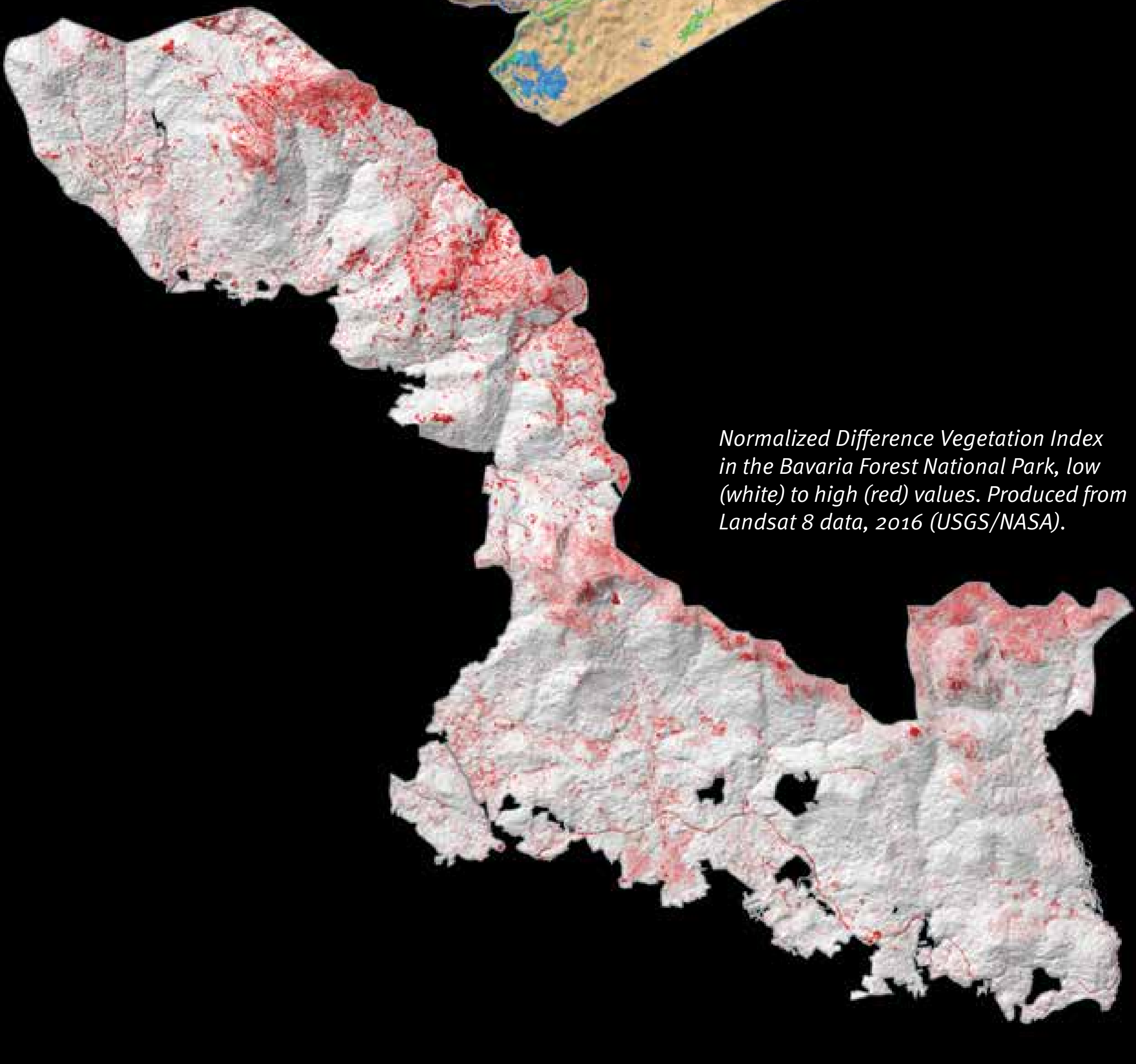
Increase experience sharing and information flow among stakeholders, and consider a coordinated capacity approach

Protected Area managers, scientists, policy-makers and other stakeholders could all benefit from improved information flow. Many Protected Areas management institutions do not have in-house technical capacity to take maximum advantage of Remote Sensing tools; it could be more effective and efficient to coordinate this capacity through European or national support mechanisms. For Protected Areas and ecosystem managers, virtual networks such as those created by GEO/GEOSS or the LifeWatch ERIC provide useful information, data, maps, models for supporting management decisions. Along these lines, an Ecosystem Community of Practice is being established by ECOPOTENTIAL and should be further supported at European level after the end of the project. The results of ECOPOTENTIAL indicate that it is important that EU conservation strategies are co-designed and co-developed with the staff of Protected Areas working on local and concrete issues.

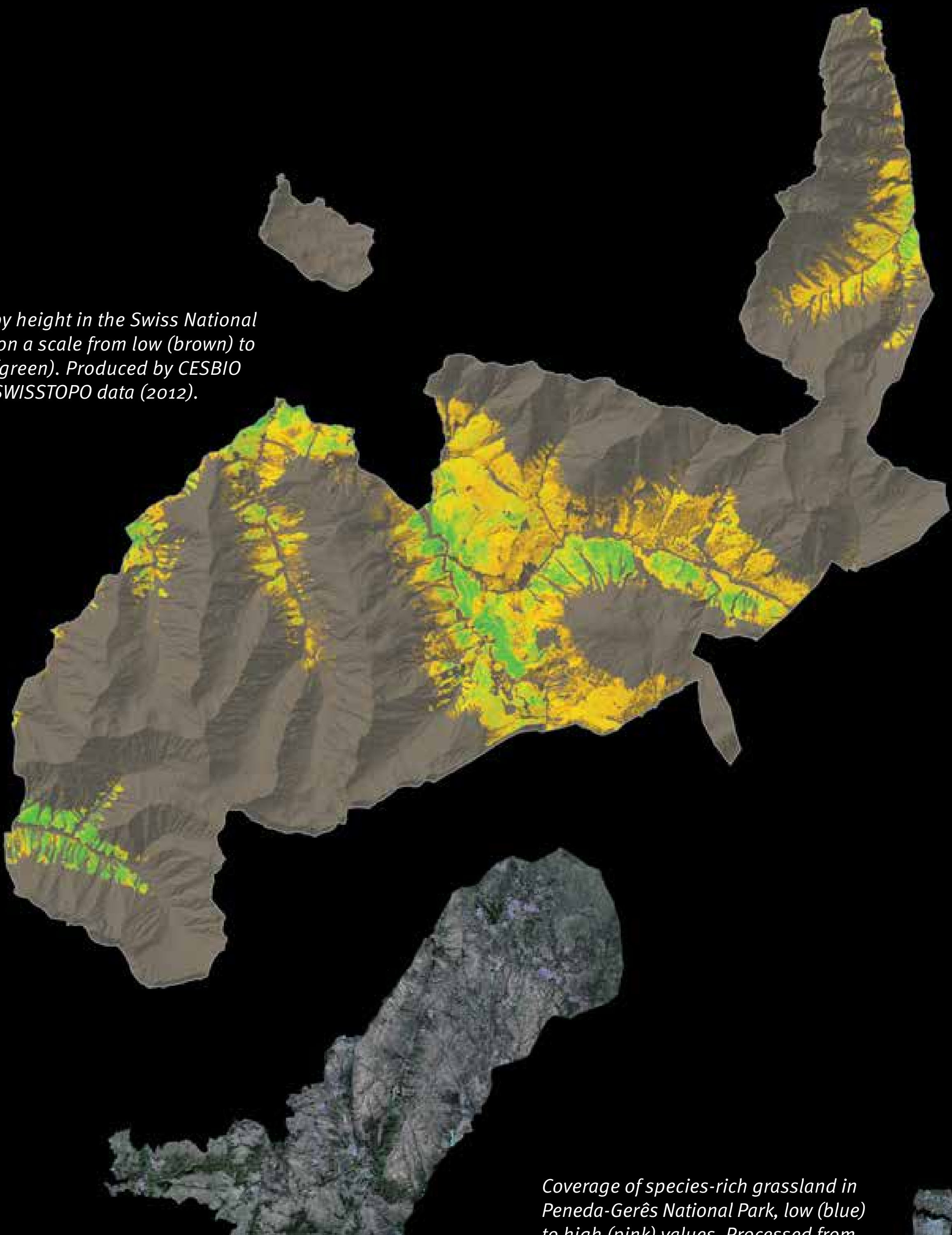
Doñana National Park. © Héctor Garrido/EBD-CSIC



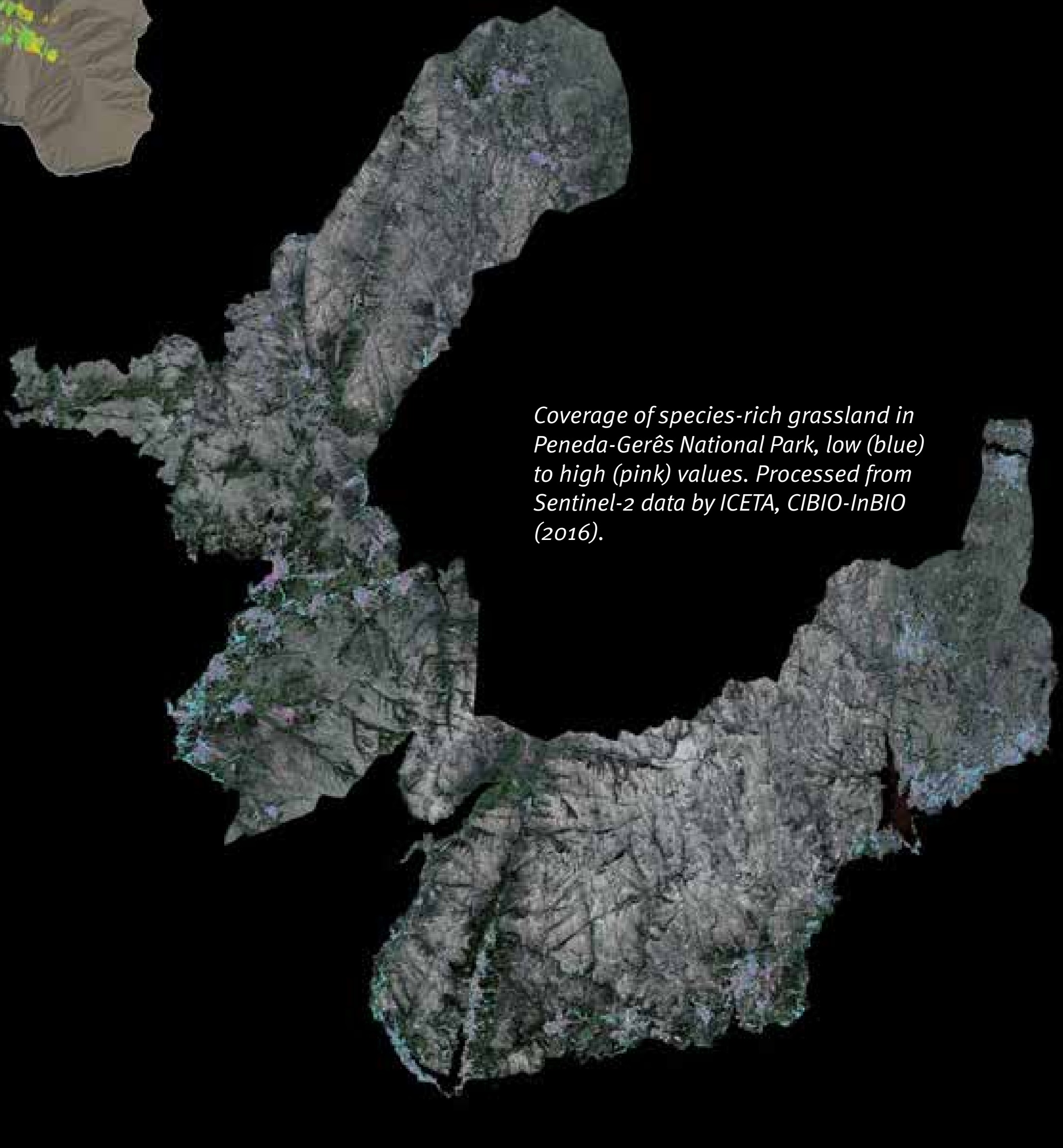
Tree cover density in Abisko National Park, low (brown) to high (green) values. Produced from Copernicus data. Processed by CESBIO.



Normalized Difference Vegetation Index in the Bavaria Forest National Park, low (white) to high (red) values. Produced from Landsat 8 data, 2016 (USGS/NASA).



Canopy height in the Swiss National Park, on a scale from low (brown) to high (green). Produced by CESBIO from SWISSTOPO data (2012).



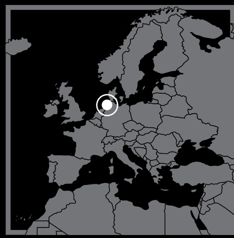
Coverage of species-rich grassland in Peneda-Gerês National Park, low (blue) to high (pink) values. Processed from Sentinel-2 data by ICETA, CIBIO-InBIO (2016).

CASE STUDY: **Wadden Sea**

The Wadden Sea is a productive estuarine area and among the largest coastal wetlands in the world. A network of national protected areas spreading across the North Sea coastline of the Netherlands, Germany and Denmark protects this remarkable area. The area is also a UNESCO World Heritage Site and is covered by the Natura 2000 network. The Wadden Sea is a biodiversity hotspot due to its unique location as a meeting point of land, fresh, brackish water and marine habitats. Wind, waves, tides and rivers have created unique coastlines, ranging from tidal mudflats and saltmarshes to deep tidal channels. More than 10 million birds live within and pass through the Wadden Sea, most on migratory routes between nesting grounds in the Arctic and wintering sites in Africa. They are attracted by the nutrients, brought by rivers emptying into the North Sea, which

Seabird, Wadden Sea. © Jan Veen

Wadden Sea composite RS-imagery from Sentinel-2 data (May, 2017).



allow cockles and mussels and other food sources to flourish. However, over the last decade, nearly half of the breeding bird species have continued to decrease. There are some indications that over-fishing, as well as insufficient roosting an d moulting areas, could be behind these dwindling populations.

ECOPOTENTIAL uses 3D models to simulate how the birds' food sources are faring in the Wadden Sea. Satellites can detect the larger mussel and cockle colonies and the algae that support these molluscs. Including the satellite data in the models improves predictions of how the food sources develop across the Wadden Sea. Policy and management strategies can also be incorporated into the models to determine how future food supply may be impacted by these strategies.

Dunes on the Wadden island of Terschelling. © https://beeldbank.rws.nl, Rijkswaterstaat

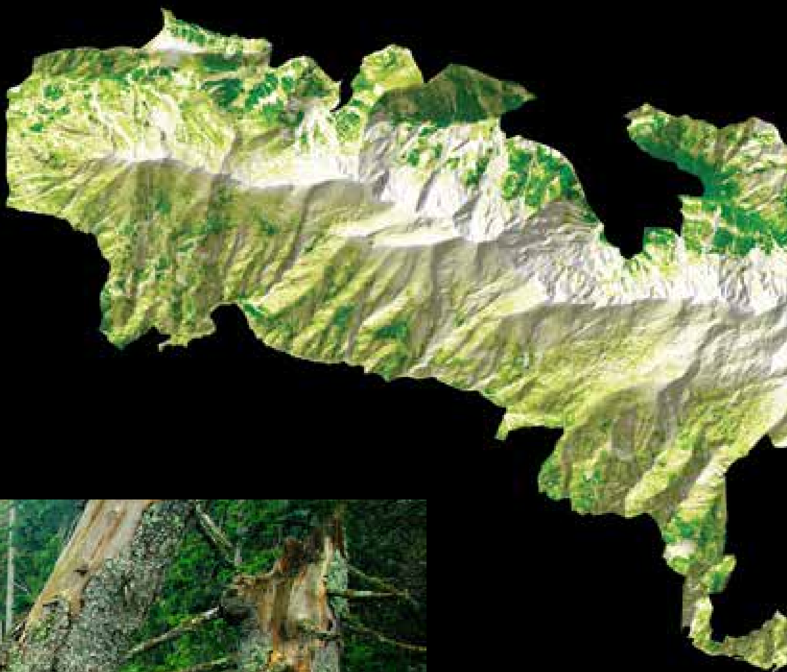
CASE STUDY: **Kalkalpen**

The mountain forests of Europe are important refuges for many vulnerable species. In addition to their ability to store carbon, acting as carbon sinks, they are also biodiversity hotspots and provide areas of recreation and outstanding natural beauty.

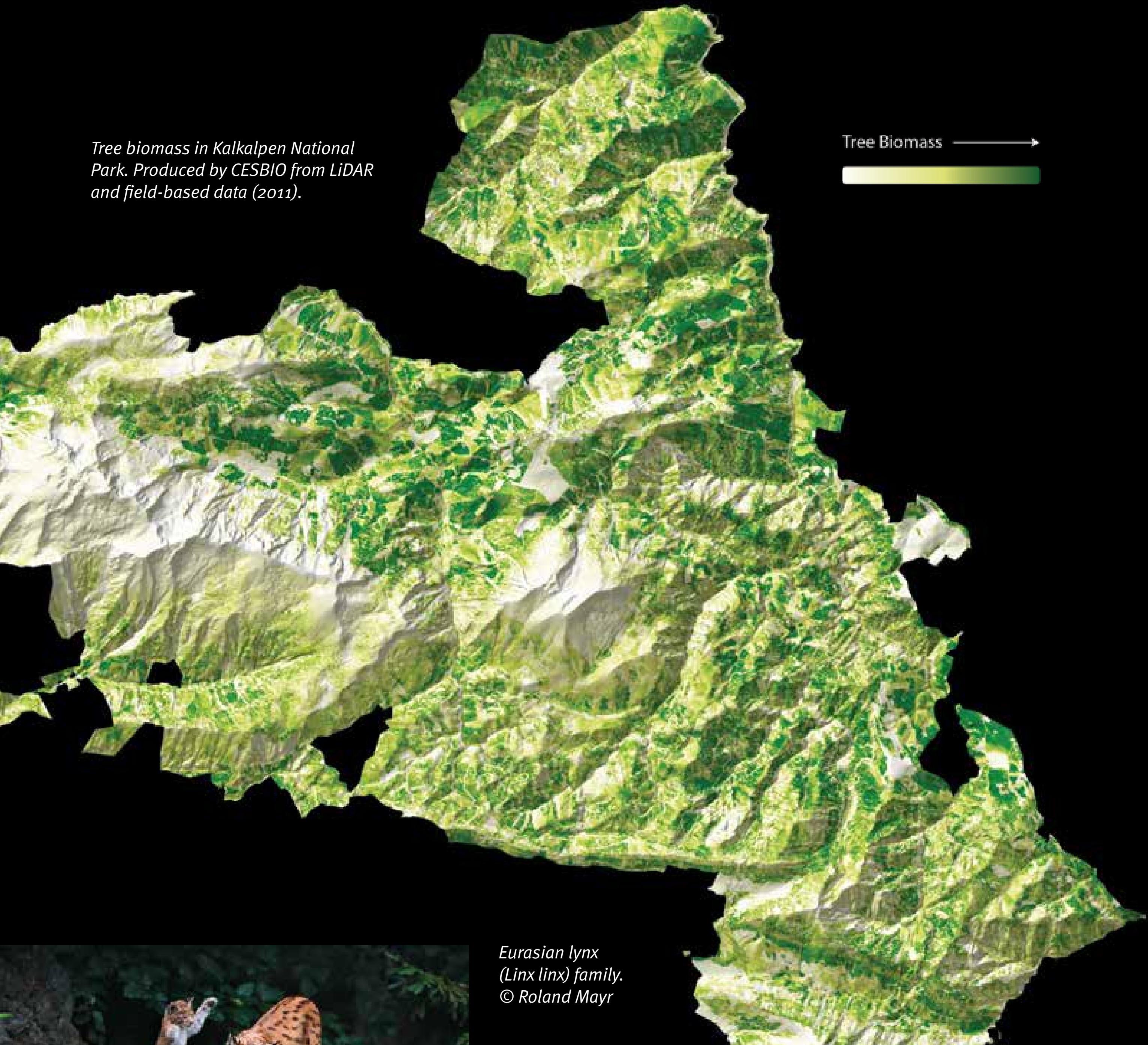
The Kalkalpen National Park in Austria is a prime example. The park contains Central Europe's largest forest, characterized by mixed spruce-fir-beech forests, subalpine spruce forests, pastures and alpine habitats. Over 900 plant species are found here (one third of all plant species in Austria), along with one of the rarest mammals in Europe, the Eurasian lynx, which has been reintroduced into the park.

Climate change is already altering mountain forest ecosystems across Europe, and will continue to do so. In the Kalkalpen National Park, higher temperatures increases the risk of bark beetle outbreaks and stronger winds are causing more damage. Certain tree species, such as Norway spruce, are dying faster than usual and new tree species are taking their place. These disturbance release high amounts of carbon into the atmosphere and reduce the forest's capacity to retain pollutants. However, they can also increase biodiversity by creating diverse habitats, with deadwood in particular constituting a key habitat for many typical mountain forest species. Herein lies the challenge for politicians and managers of protected areas.

Ecosystem models are used to assess the effect of storms and insect infestations on carbon loss to the atmosphere and nitrate loss to groundwater. At the same time, satellite data is analysed to improve forest vegetation inputs to the model for the entire park area also considering various climate change scenarios. Model results will provide guidance as to how bark beetle and wind disturbance should be managed to optimize both carbon sequestration and biodiversity.



Fallen trees, Kalkalpen National Park. © Erich Mayrhofer



Tree biomass in Kalkalpen National Park. Produced by CESBIO from LiDAR and field-based data (2011).

Eurasian lynx (Linx linx) family. © Roland Mayr

CASE STUDY: **Montado**

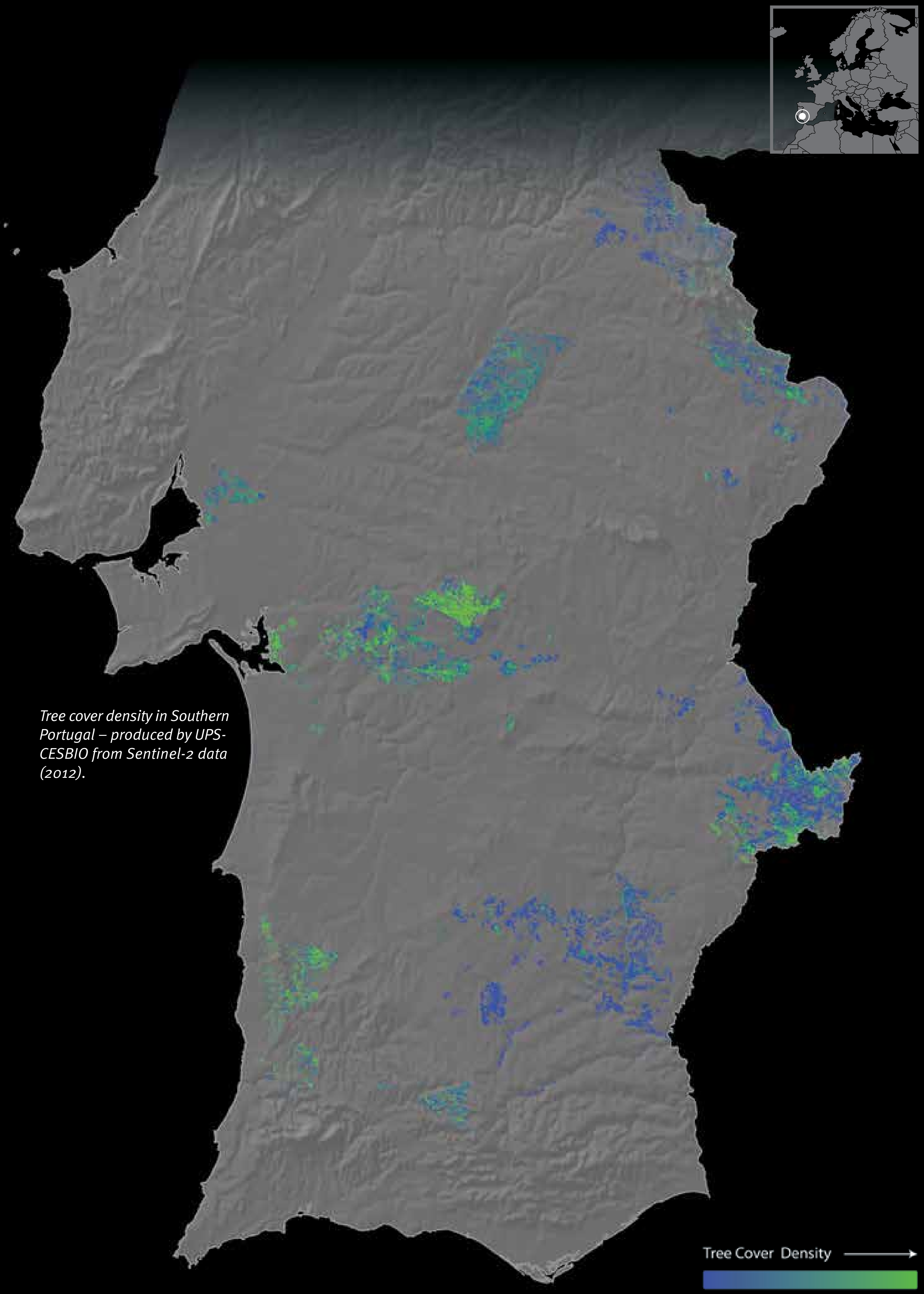
Montado is a traditional wood-pasture system where cork and holm oaks are the dominant trees. Rich in biodiversity, montados are listed under the EU Habitats Directive, constitute a key habitat in various sites in the Natura 2000 network, and are considered high nature value farmland.

Cork, which is harvested every 9–12 years, is the most important forest product from montados, with Portugal producing 54 per cent of the world's cork. Livestock provides another source of income in these areas, while from a cultural and recreational perspective, montados are valued for their landscape aesthetics, natural values and cultural heritage.

Water, nutrient cycles and soil erosion are important regulating services to be managed in montados, where the main threats are water stress due to more droughts and warmer summers, soil degradation from overgrazing and tillage, pests and disease. The current lack of regeneration and the death of adult trees are of serious concern and may lead to a loss of montados and replacement by shrubland. The correct management of soil, grazing and the overall habitat can counteract these threats. For example, protecting and restoring the soil is central for tree health.

The ECOPOTENTIAL project is using indicators, such as Tree Cover Density or Leaf Area Index, to monitor changes in tree distribution and health. This information, combined with field data, allows researchers to better assess the age structure of montados, pasture growth, and soil and water dynamics. With this knowledge, the state of large areas of montado can be regularly assessed using Earth Observation, farmers can be better advised, and management practices can be continuously improved.

Montado in Southern Portugal. © Rui Cunha



Tree cover density in Southern Portugal – produced by UPS-CESBIO from Sentinel-2 data (2012).

ECOPOTENTIAL
Improving future ecosystem benefits through Earth Observations

Further information and contacts:

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This project is funded by the European Union