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SPACED

Using Earth Observations to Protect Natural Landscapes

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SPACED

Using Earth Observations to Protect Natural Landscapes

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Context
This book completes and extends the photo exhibition "SPACED: Using Earth Observation to Protect Natural Landscapes" prepared by CNR, UNEP, GRID-Arendal and CREAF, which illustrated the ECOPOTENTIAL project, that took place from January 8 , 2018 to January 12, 2018 at the European Parliament in Brussels.

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Presentation

Traditionally, protected areas were managed through decisions taken based on local knowledge combined with data collected on the ground and carefully produced by scientific field campaigns carried out on selected plots and along selected transects. However, these in-situ measurements often covered only a tiny portion of the protected area, as a result generating potentially fragmented information. Under these circumstances, protected area experts were forced to empirically extrapolate local information to the whole region in order to design and apply conservation measures to preserve biodiversity, ecological integrity and ecosystem services.

Remote sensing data acquired by Earth observation satellites (such as the new European Sentinel fleet) is a game-changing technology that, for the first time, gives managers a comprehensive bird's-eye view of the geobiophysical variables that are regularly used to assess the status of their protected areas. But the images produced are much more than merely large selfies. Satellites measure the Earth in several ways. Firstly, passive instruments gather reflected sunlight at specific frequencies (called bands) that, for example, are sensitive to the presence of greenhouse gases in the atmosphere or to chlorophyll in plants. Secondly, some active instruments emit radar signals that can penetrate the clouds and measure small changes in topography, and lastly, use the same sensor detects the radiation that is backscattered from the target. The major advantage of this technology is that data acquisition can be performed at high frequency or even continuously in space and time, allowing for a precise determination of the distribution of the trends in the whole region.

The use and application of remote sensing requires new tools and new expertise that have been developed by scientists in recent years. This knowledge is now mature enough to be transferred to protected area managers for its operational usage.

This book focuses on 24 protected areas that are part of the ECOPOTENTIAL project and describes a collection of scenarios where Earth observation data is essential, accompanied by visual maps covering the whole extension of each protected area. The main purpose of this volume is to illustrate the capabilities of remote sensing and how this technique is being applied in many ways to monitor several different aspects of ecosystems and environmental conditions. Each type of ecosystem (mountain, arid or coastal and marine) presents different challenges that will be addressed through different Earth observation and data analysis approaches.

We trust that this book will illustrate the extent to which Earth observation by satellites has become a crucial tool for obtaining a global view of natural ecosystems, as well as for monitoring ongoing changes and supporting knowledge-based conservation and management strategies.

Joan Masó and **Cristina Domingo**
CREAF

ECOPOTENTIAL partners

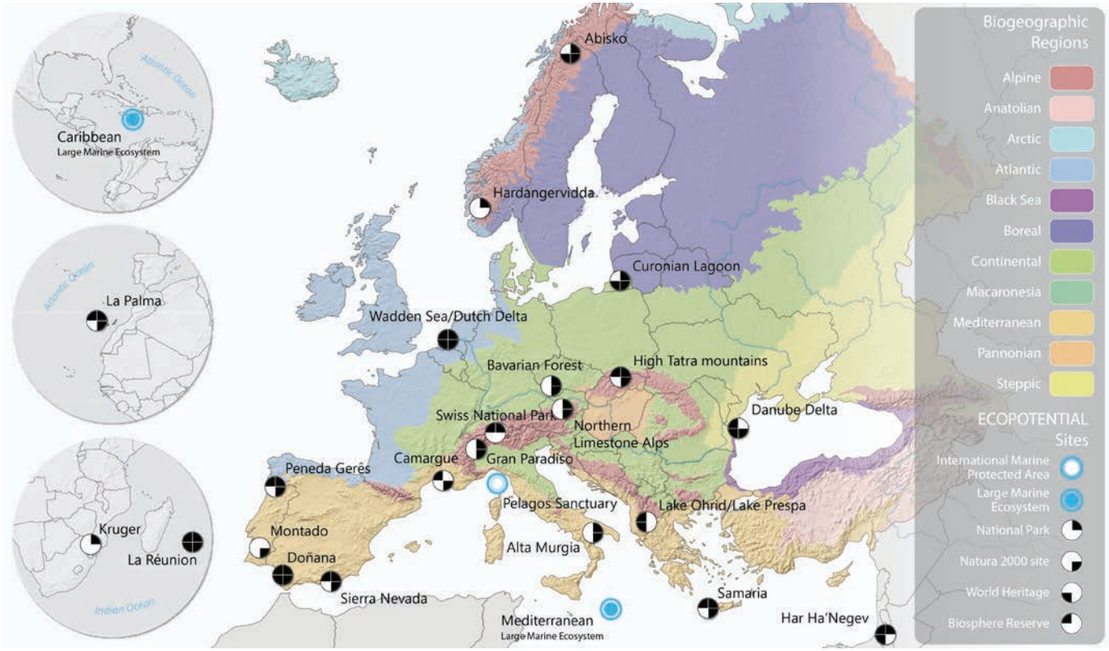
ECOPOTENTIAL in a Nutshell

Terrestrial and marine ecosystems provide human societies with essential goods and services. However, in the last decades, anthropogenic pressures have altered many ecosystem functions that are essential for human wellbeing as well as climate regulation at local and regional scales. To improve ecosystem benefits, knowledge-based conservation, management and restoration policies are urgently needed. Fundamental to this goal is the effective monitoring of the state and trends of ecosystems. From the Sputnik to the European Sentinels, passing through the iconic Earthrise image of Apollo 8 taken fifty years ago, our ability to monitor and observe the planet from space has dramatically increased, leading to the possibility of detecting the health state and ongoing changes of environments and ecosystems at local to global level.

ECOPOTENTIAL, a large European H2020 project, develops its pilot actions in a set of internationally recognized protected areas in Europe and beyond, spanning all biogeographical regions of Europe and focusing on mountain, arid and semiarid, coastal and marine ecosystems. The project delivers Earth observation products to monitor, understand and predict changes in ecosystems and ecosystem services, supporting knowledge-based management and conservation of protected areas. The project focuses both on changes taking place at continental level as well as on specific conservation challenges linking research to the local needs of protected area management. This book provides examples of the way satellite observations, field data and conceptual approaches are combined to address some of the most pressing issues affecting the natural ecosystems in the project's protected areas, working closely together with stakeholders and decision-makers.

ECOPOTENTIAL's conceptual view is that ecosystems are "one physical system" with their environment, and they are characterized by strong interactions across multiple space and time scales. ECOPOTENTIAL has strong links with many other international programmes, such as the GEO Global Ecosystem Initiative (GEO ECO), the European Long-Term Ecological Research Network (eLTER), GEO BON and the European LifeWatch Infrastructure. All data, model results and knowledge will be available on common and open platforms, contributing to the Global Earth Observation System of Systems (GEOSS). In this way, ECOPOTENTIAL will benefit different communities, scientists, protected area managers and citizens.

ECOPOTENTIAL Project Sites



Ecosystem services

Some of the most relevant Ecosystem Services for a protected area are indicated in **bold** in the right column of each page. This information is based on the "*Deliverable 11.2 Synthesis study on integration of EO data/ tools in decision making*" (http://www.ecopotential-project.eu/images/ecopotential/documents/D11.2.pdf) developed in the context of the ECOPOTENTIAL project. For Abisko, Bavarian Forest National Park, Réunion, the Mediterranean Large Marine Ecosystem and Pelagos Sanctuary, the information has been extracted from specific ECOPOTENTIAL storylines (narratives that describe the analysis of the ecological issue under study and the research workflow) and validated with researchers working at the protected areas. Further information can be found on the project's website: http://www.ecopotential-project.eu

Legend

Ecosystem types and protected area category


Mountain Ecosystems


Arid Ecosystems


Coastal and Marine Ecosystems


National Park


Natura 2000 site


World Heritage


Biosphere Reserve

Country

AL GR MK Albania, Greece, North Macedonia

AU Austria

CH Switzerland

DE Germany

DE DK NL Germany, Denmark, Netherlands

FR France

GR Greece

IL Israel

IT Italy

IT MC FR Italy, Monaco, France

NO Norway

PL SK Poland, Slovakia

PT Portugal

RO UA Romania, Ukraine

ZA South Africa

SE Sweden

SP Spain

Accuracy of maps

Further information requests related to the accuracy of the remote sensing maps and products in this book can be addressed to the authors through the email info@ecopotential-project.eu.
Maps included in this booklet can be found at http://maps.ecopotential-project.eu/.

New Perspective from Space

In 1946, planet Earth took its first selfie. A camera was mounted on a German rocket in New Mexico, United States and launched 100 km into space before returning with exposed photographic film. Since then, Remote Sensing technology has improved immensely, as you can see from the images of this book. Modern satellites with a range of sensors are orbiting around us while continuously providing new and valuable information on our planet. The unprecedented availability of satellite time series completes field measurements and allows us to understand large scale changes in our environment and how best to protect it.

Earth observation satellites record electromagnetic energy reflected or emitted by objects on the Earth's surface, capturing not only the part of the electromagnetic spectrum that is visible to the human eye (visible light), but also other wavelengths such as the infrared, including thermal and microwave radiation. This allows us to see reality at an unprecedented detail and distinguish between different surfaces because they reflect solar radiation differently. Existing satellites provide data at a range of different spatial resolutions and temporal intervals that can be selected depending on our needs. Weather forecasting requires frequent data, while monitoring changes in agriculture or natural vegetation generally requires images at a weekly, monthly or yearly basis. Spatial resolutions can vary from less than one meter to a few kilometres, allowing Earth observations to inform us about our planet from local to global scales. Thus, the availability of sensors characterized by a range of spectral, spatial and temporal resolution offers new perspectives in Earth surface monitoring.

Some of the Satellites Informing ECOPOTENTIAL

Several Earth observing satellites, such as Landsat and many others, are now orbiting the Earth.

In particular, the European Sentinel-2A and 2B are twin satellites, which oppose each other in orbit. Their data, freely available, can support the monitoring of land surfaces, providing quantitative information on deforestation, crops condition, glacial or snow melting, as well as emergency response services. These two Sentinels can capture images at spatial resolutions ranging from 10 to 60 meters every 5 days, and ensure continuity to data acquired in the past, as the optical Landsat data archives. Thus, having access to long-term environmental data records can offer the perspective to detect changes and trends useful to predict new scenarios.
Sentinel-3A, on the other hand, focuses on observing the weather and oceans, including sea ice, ocean temperature and water quality. It carries a suite of instruments, including a radar altimeter, and will provide continuity to other satellites such as ERS, Envisat and SPOT.

The Sentinel family was created by the European Space Agency for the Copernicus Programme and comprises additional future Sentinel missions to monitor the health of our planet. Specifically, Sentinel-4 and Sentinel-5 will provide data for atmospheric composition monitoring from geostationary and polar orbits, respectively. In addition to optical sensors, radar Sentinel-1 sensors are providing day and night radar images at all weather conditions for land and ocean services.

Mountain Ecosystems

Gran Paradiso National Park, Lake Dres ©AP

Abisko

SE

Abisko treeline advancement or retreat is a sensitive indicator for ecosystem responses to climate change. Earth observation is needed for long-term monitoring.

Abisko National Park, located 200 km inside the Arctic circle in Sweden, was founded in 1909 to protect 77 km^2 of the scenic Abiskojåkka valley, which hosts rare plant and bird species. With the iconic valley of Lapporten nearby and the likelihood of witnessing the aurora borealis (commonly known as the Northern Lights), Abisko is an ideal destination for experiencing Sweden's northern mountainous landscape.

Ⓐ The importance of boreal regions

Abisko's plants and animals are characteristic of Arctic and subpolar regions. Arctic birds, moose, lynx and wolverine are common. Semi-domesticated reindeer roam the tundra and alpine grasslands, herded by the Sami Indigenous people. The park is located on the border between two important northern ecosystems. Here, the northern limit of boreal birch forest meets the southern fringes of tundra. This transition zone is very sensitive to climate change, making Abisko an interesting area for scientists to study. Findings from Abisko could potentially be applied to a huge area in Northern Europe, Asia and America.

Tree-line birches are twisted by the wind. Abisko National Park is in the valley and on the mountainside behind the birches. ©SW

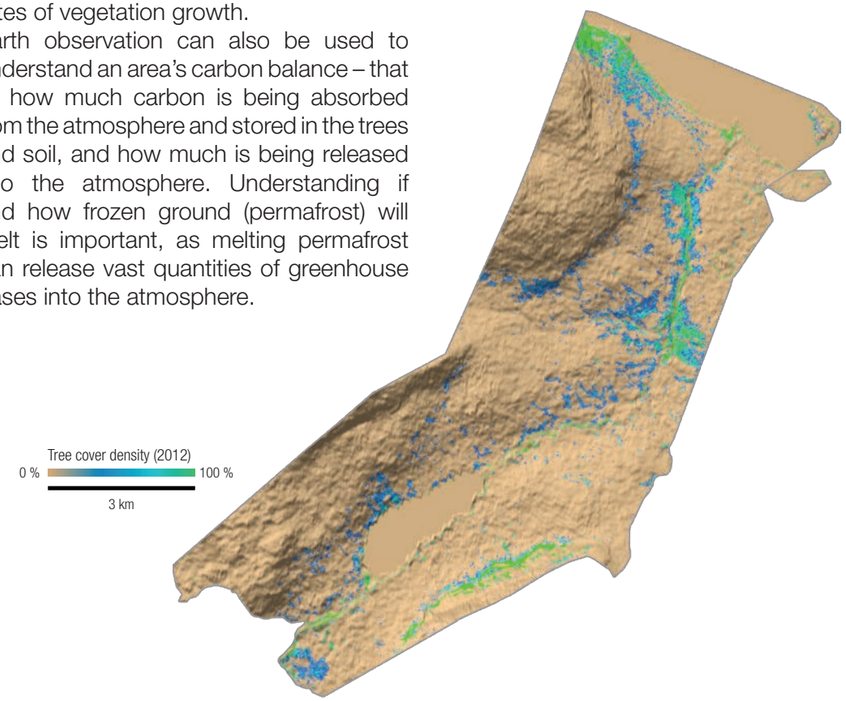
Lapporten, the large U-shaped valley formed by glacial erosion, is Abisko's most distinctive landmark. ©CD

Mires, dominated by cottongrass (*Eriophorum scheuchzeri*) and sphagnum moss, are an important carbon sink ©SW

Ⓑ Climate change monitoring from space

One question scientists want to answer is how climate change will affect the landscape: the treeline could advance north and upward, as conditions become warmer. At the same time, a warmer climate improves the conditions for insects feeding on leaves and more frequent and severe insect outbreaks could push the treeline further south. The ECOPOTENTIAL project is using satellite imagery to detect the treeline, in order to find out whether the forest will advance due to warming or retreat due to insect herbivory. Other important processes can also be tracked, including phenology and rates of vegetation growth.

Earth observation can also be used to understand an area's carbon balance – that is, how much carbon is being absorbed from the atmosphere and stored in the trees and soil, and how much is being released into the atmosphere. Understanding if and how frozen ground (permafrost) will melt is important, as melting permafrost can release vast quantities of greenhouse gases into the atmosphere.



Tree cover density map (2012) which shows how birches reach the northern and altitudinal limits of their habitat, gradually giving way to the tundra. Produced by Copernicus Land Monitoring Service with funding from the European Union. Post-processed by CESBIO-UPS for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
erosion prevention
pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

Bavarian Forest National Park

DE

Climate change could result in community composition changes in the transition zone between deciduous and coniferous montane forests, which must be monitored.

The Bavarian Forest National Park (Nationalpark Bayerischer Wald) and the neighbouring Šumava National Park (Czech Republic) form the largest area of closed forest in Central Europe (242 km^2), and one of the very few natural forest ecosystems remaining in the Central European mountains. Established in 1970, this protected area rich in springs, brooks and rivers, was the first national park in Germany. Besides its deciduous and coniferous forests, its wetlands and raised bogs are important habitats with high value for nature conservation.

Ⓐ Forest sensitive to changing environmental conditions

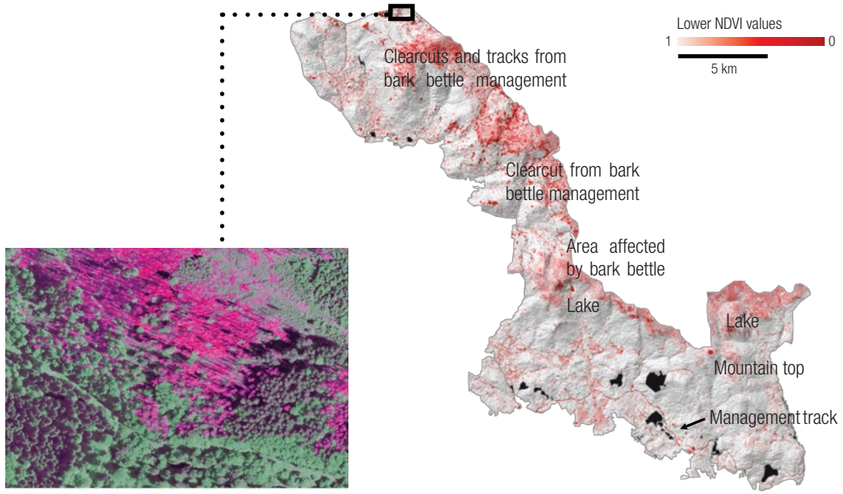
The park's tree species diversity is relatively low due to natural factors. This makes the forest particularly sensitive to changing environmental conditions. For example, in the lower altitudes of the park, former plantations of spruce (which is naturally only dominant on the highest ridges) are exposed to natural dynamics. This is leading to spruce being replaced by deciduous species, mainly beech. Both species are contributing to vegetation structure and to main biomass.

Natural dynamics create a highly diverse structure and many habitats for large numbers of animals, plants, and fungi. ©CB

Former plantations of conifers (***Picea abies***) are naturally being replaced by deciduous species, mainly beech (***Fagus sylvatica***). ©AP

Ⓑ Ecological succession monitoring

At higher elevations, bark beetle outbreaks in recent decades caused a large-scale breakdown of conifer forests, with mild winters combined with prolonged, warm and dry summers helping support several generations of bark beetles per year. Although natural regeneration and ecological succession are now under way, development is very slow because competitive grasses are inhibiting tree regeneration. Impacts including acid rain, climatic extremes and airborne nitrogen pollution are also hindering progress. Within the ECOPOTENTIAL project, Earth observation tools and remote sensing are being used to better understand how vegetation is evolving across the park and over time. Earth observation is applied to detect patterns of dominant plant species, link habitat characteristics with terrain and track animal movements. The park administration itself is also carrying out intensive research on tree regeneration, the role of dead wood, and the impact of global warming and extreme climatic events on the future development of these ecosystems.



Right: USGS/NASA Landsat 8 OLI Normalised Difference Vegetation Index (NDVI) (2016-07-10) which shows the presence and health of vegetation. Slightly red areas, representing lower values, are affected by bark beetle outbreaks. Left: Details of colour-infrared imagery reveals the mosaic of healthy forest (in light green and grey) and dead standing trees or dead wood on the ground (in pink & purple). Produced and processed by UAB for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
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spiritual significance

Gran Paradiso National Park

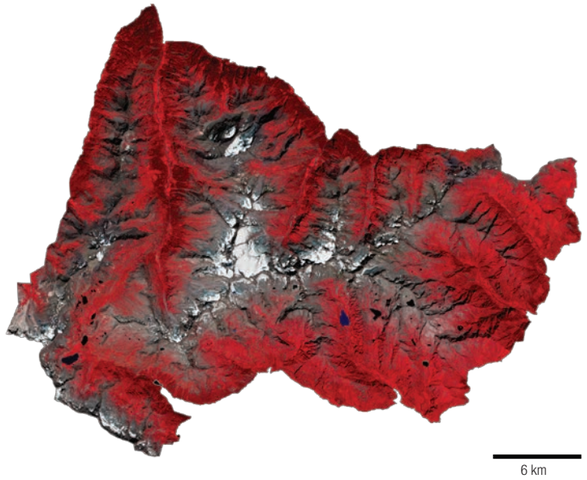
The abandonment of traditional mountain grassland management practices is changing plant composition and decreasing biodiversity of this essential habitat.

The Gran Paradiso National Park covers about 700 km^2 and ranges from 800 to 4,000 metres above sea level. The oldest national park in Italy, it contains deciduous and evergreen forests, grasslands, glaciers and high-altitude environments. The park hosts the original surviving population of the charismatic Alpine ibex (*Capra ibex*), as well as other specialized herbivores such as the Alpine chamois and the Alpine marmot. It borders the Vanoise National Park in France, creating a large international protected area in the heart of the south-western Alps.

Ⓐ Monitoring grasslands

Mountain grasslands, essential to large herbivores, are semi-natural habitats that are, to an extent, the result of agropastoral activities. The abandonment of traditional management practices is therefore changing the plant composition of many grasslands, leading to tree encroachment and affecting the net ecosystem CO_2 exchange. Abandoned grasslands also show a pronounced decrease in biodiversity.

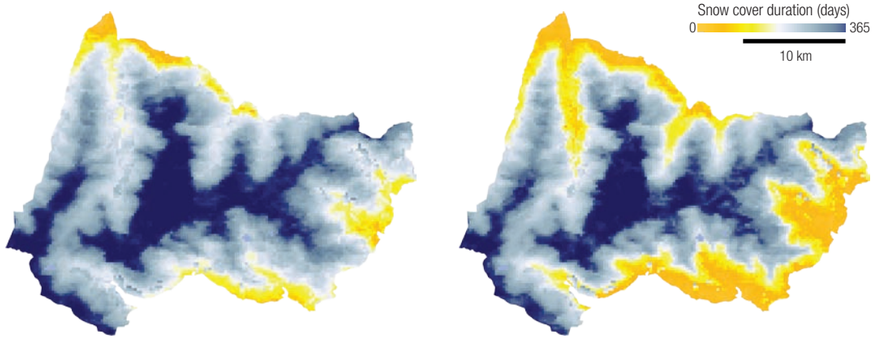
The Nivolet plain was formed by glacial erosion from the quaternary period. It is the highest alpine grassland in the Alps (2,700 m.a.s.l.). Several glacial lakes contribute to the beauty of this landscape and make it a favourite spot for hikers. ©AP



Sentinel-2A 2016-08-23 (False colour). Red and brown areas correspond to active vegetation (forest and prairies) while grey and white areas correspond to rocky and snow covered land. Produced from ESA remote sensing data (Sentinel-2A). Image processed by CREAF for ECOPOTENTIAL.

Ⓑ Snow cover changes

Climate change is an additional risk factor. As changes in snow and rainfall can alter the soil water available to plants, a steep decline in specialized montane plant species is expected in the next decades. Owing to increasing temperatures and decreasing snow cover, plants are also likely to green up earlier, which will pose a threat to large herbivores as nutritious grasses must be available in late summer to successfully wean their juveniles. Snow monitoring is essential to understand these changes, that is specially evident in the valleys, where the snow cover duration changes significantly between winter seasons.



MODIS Terra-Aqua Snow Cover duration product for 2008-2009 (left) and 2011-2012 (right) seasons. Yellow areas correspond to areas with less snow cover days per year. During season 2011-2012, valleys were less affected by snow cover. Produced by EURAC for ECOPOTENTIAL.

Chamois (*Rupicapra rupicapra*) is the most abundant ungulate in the park. ©AP

Scheuchzer's cottongrass (*Eriophorum scheuchzeri*) grows on the shore of alpine glacial lakes. ©AP

Tree encroachment on abandoned mid-altitude valleys is controlled by reintroduced traditional mowing. ©IS

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Hardangervidda National Park

NO

Grazing pastures are essential for the largest wild reindeer population in Europe, hosted on the largest mountain plateau in northern Europe.

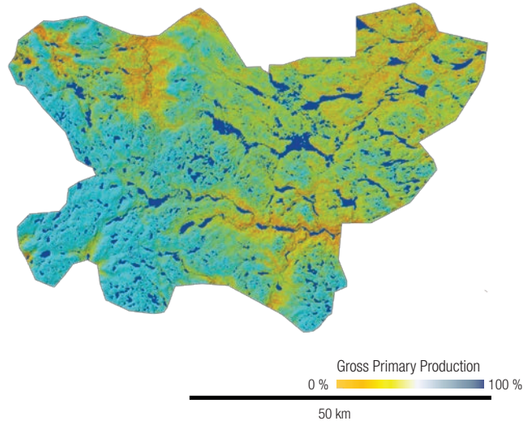
Hardangervidda, located in southern Norway, is the largest mountain plateau in northern Europe. The area hosts the largest wild reindeer (*Rangifer tarandus*) population in Europe, which migrates across the plateau in search of food and suitable calving grounds. The park is also popular for hiking, hunting and skiing.

Ⓐ Monitoring grazing pastures

Changes in the availability and quality of winter and summer grazing pastures can therefore greatly affect the reindeer population. In addition, a warming climate can increase insect harassment, which reindeer are increasingly suffering from in the summer. Human disturbance, such as the building of recreational cabins, roads and power lines, snowkiting and hunting, can also limit or prevent reindeer from accessing important grazing and calving areas.

Gross Primary Production estimated from satellites helps us to quantify how much vegetation is available in summer grazing grounds used by wild reindeer.

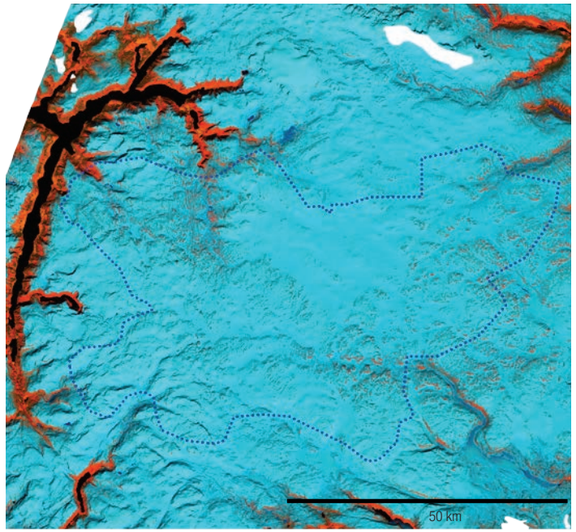
Cairns like this one mark the tourist paths which are more frequented for hunting, fishing, skiing and hiking; such activities can limit reindeer to access important grazing and calving areas. ©TB



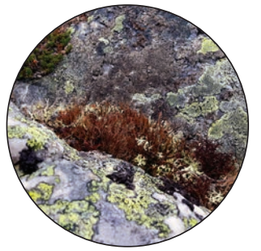
MODIS Terra-Aqua Gross Primary Production map. Produced by UFZ for ECOPOTENTIAL. Digital Elevation Model from Kartverket/ Geonorge.

Ⓑ Reindeer population: an essential value

The reindeer population (estimated at 9,000 to 12,000 individuals) is important not only for its ecological value, but also for its economic and recreational value for hunters, hikers and landowners. A loss of this herd would have a negative impact not only on the ecosystem, but also on the people that depend on it for their livelihood. In the winter, the reindeer rely greatly on lichens as a food source, which they reach by digging through the snow. In the summer, they depend on lush summer pastures to be able to feed their calves and to fatten themselves up before the long winter. ECOPOTENTIAL uses satellite imagery, GPS collar data and data gathered in the field to monitor reindeer population and their environment and predict changes.



USGS/NASA Landsat 8 OLI 2016-08-05 (False Colour). Small dark patches of water are surrounded by active vegetation in red, and blue snow-ice. Blue dots are the limit of the park. Processed by UAB for ECOPOTENTIAL.



Lichens are an important food source for reindeer in the winter, when other vegetation is scarce. ©TB

Here, calves are born in May. The calving time is highly synchronized with the onset of spring so that the animals can make use of the short summer season. ©OS

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aesthetic quality
spiritual significance

High Tatra Mountains

PL SK

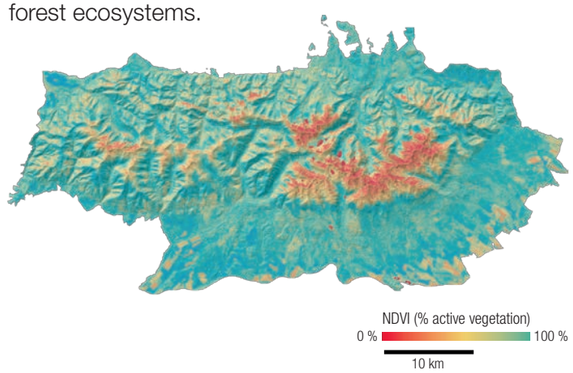
Ensuring the health of Tatras forests (two thirds of the area) and studying the dynamics of disturbances are essential to promote ecosystem recovery.

The Tatra Mountains straddle the border between Poland and Slovakia and are part of the larger Carpathians mountain range. With an area of just under 800 km^2, they are often referred to as the smallest high mountain range in the world. They are protected by two national parks, one in Slovakia and one in Poland; both are part of the Natura 2000 network and are included within a UNESCO Biosphere Reserve.

Ⓐ Forests: the ecosystem most under threat

Around two thirds of the Tatras are covered by forest. Unsustainable forestry practices (primarily in the nineteenth century and lasting until the 1930s) resulted in the widespread planting of Norway spruce in lieu of natural mixed beech-fir forest in the lower montane zone. This created forests with low diversity—a forest 'monoculture', which tends to be less resistant to climate change, windstorms, bark beetle outbreaks or other disturbances, such as air pollution or water shortages. As a result, the Tatras have experienced episodes of massive dieback of Norway spruce over the past few decades. Seen as a calamity from a human perspective, such dieback nevertheless gives nature a chance to recover and gradually return to the more natural mixed forest ecosystems.

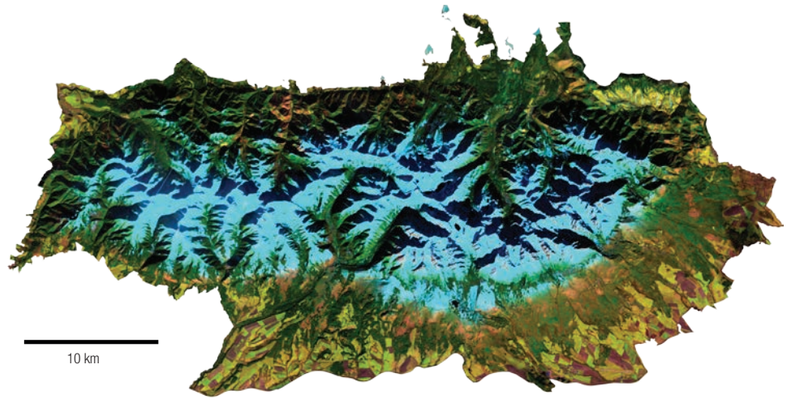
Kościeliska Valley in the Polish Tatras. Left: Spruce monocultures in the lower montane zone flank the valley meadow. Right: The same area after a windstorm in 2013. ©AB



Sentinel-2A Normalised Difference Vegetation Index (NDVI) (2017-10-02) of the two national parks which encompass the High Tatra Mountains. Green/turquoise areas indicate vegetation in good condition. Yellow areas indicate poorer vegetation due to phenology cycles or ecosystem disturbances. Red are areas with little or no vegetation mainly located in the high altitudes. Produced from ESA remote sensing data (Sentinel-2A). Processed for ECOPOTENTIAL.

Ⓑ Mountain topography: ice-shaped

Although the Tatras no longer have glaciers, they were shaped by glacial and periglacial processes during the last Ice Age, creating a unique alpine landscape boasting landforms such as U-shaped valleys, rocky peaks and mountain lakes – supplemented by limestone cliffs and caves.



USGS/NASA Landsat 8 OLI 2017-11-06 (False Colour). Vegetation appears in shades of dark and light green, while areas covered in snow appear in blue. Processed by CREAF for ECOPOTENTIAL.

The Polish Tatras seen from the north. The iconic and extremely popular Mount Giewont can be seen along with the Red Peaks Massif lying on the main ridge. ©MB

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
erosion prevention
pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

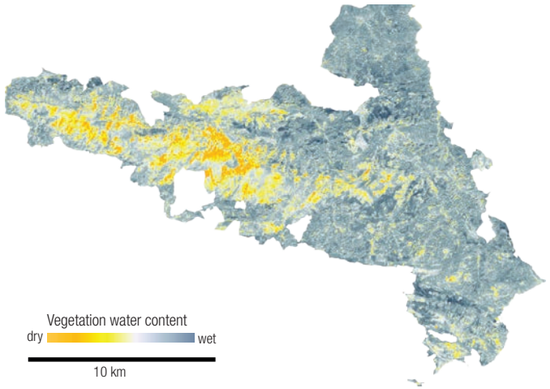
Kalkalpen National Park

The mountain forests of Europe are important habitats to preserve because they are able to store carbon and act as a "sink" for current and future carbon emissions.

Kalkalpen National Park in the Northern Limestone Alps (Austria) is one of the largest distinct forest areas which has not yet been fragmented by public transportation routes and human habitation. It covers a representative variation of environmental conditions of the montane forest belt on limestone bedrock of the European Alps. The Park is also a hotspot of biodiversity and provides areas of recreation and outstanding natural beauty.

Ⓐ Relevant ecosystem service: water resource

Karst areas, such as the national park, provide 50% of the drinking water resources for the Austrian population. Karst water is highly vulnerable to ecosystem changes since vegetation and soils are often the only filter against pollution. Forests provide the most efficient protection of the karst water via runoff buffering and retention of potential pollutants in the soil.



Sentinel-2A 2016-08-27 Vegetation Water Content product. Produced by CREAF for ECOPOTENTIAL.

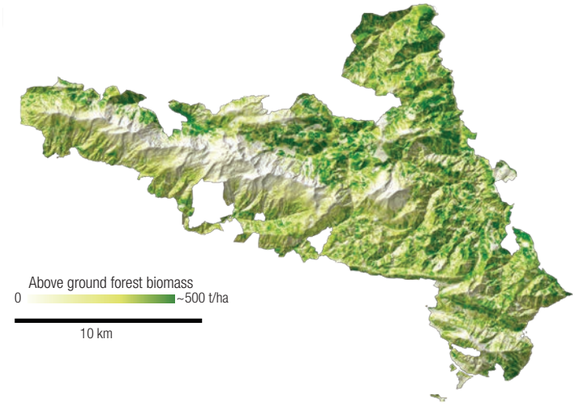
Ⓑ Natural habitat for endangered species

The National Park Kalkalpen in Austria is a prime example. The park has Central Europe's largest forested area, characterised 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 lynx (*Lynx lynx*), which has been reintroduced on several occasions into the park.

Lynx (*Lynx lynx*) is one of the rarest mammals in Europe ©RM

Ⓒ Monitoring climate change threats: forest disturbances

Climate change is already altering the forest mountain ecosystems across Europe and will continue to do so in the future. In the Kalkalpen National Park, higher temperatures are increasing the risk of bark beetle outbreaks, and winds are rendering stronger damage. Certain tree species such as Norway Spruce are dying faster than usual, and new tree species are taking their place. These kinds of disturbance release high amounts of carbon into the atmosphere and reduce the forest's capacity to retain pollutants such as nitrogen. Earth observation data is essential to easily monitor the effects of storms and insect infestations.



LiDAR data Above Ground Forest biomass product (2011). Produced by CESBIO for ECOPOTENTIAL.

Forest disturbances can increase biodiversity by creating diverse habitats, and because deadwood is a key habitat for many typical mountain forest species ©EM

The ECOPOTENTIAL project is supporting fact-based decision-making within the park in these times of rapid change. Satellite data is analysed to improve forest vegetation inputs to the model for the entire park area. Model results will provide guidance to protected area managers and politicians as to how bark beetle and wind disturbance areas should be managed to optimise both carbon sequestration and biodiversity.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

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pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

La Palma Island

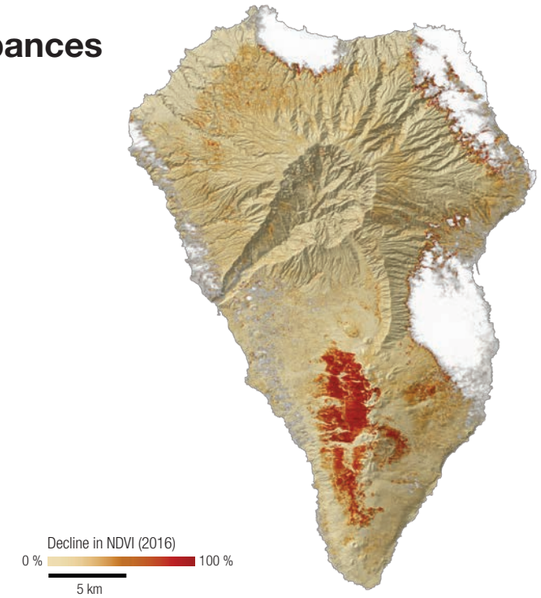
The vegetation of the park is characterized by a high proportion of endemic plant species highly threatened by global extinction, which may imply biodiversity loss.

The volcanic island of La Palma (also known as “La Isla Bonita” or “La Isla Verde”) is the only island in the Canary Island archipelago with permanent rivers. Thanks to its large variation in altitude (its highest point reaches 2,426 m) and its isolation in the Atlantic Ocean, La Palma has very high biodiversity. Many of its species are native (endemic) to the island or the archipelago. For these reasons, the whole island became a UNESCO Biosphere Reserve in 2002 and also hosts a national park (Caldera de Taburiente) and various other protected areas.

Ⓐ Monitoring forest and fire disturbances

The island hosts large natural forests, which are very important in capturing large amounts of humidity from the permanent cloud cover on the northern and eastern slopes, which provide fresh water to aquifers and the island’s inhabitants. However, fires, a source of potential threat to biodiversity, occur naturally on the island and the native conifers are adapted to them. When the flames are raging through, burning down needles and small branches, the stems survive and resprout quickly afterwards. However, the changing climate could lead to more frequent and severe fires in the future.

Canary pine (*Pinus canariensis*) is perfectly adapted to forest fires. It can resprout from all parts of the plant even after devastating fires. ©CB



Decline in NDVI product derived from Sentinel-2A (2016) which shows the loss of vegetated area in the southern part of La Palma between July and August 2016 due to a fire episode. Clouds, which continuously form due to trade winds, cover the white areas on the map. Produced from ESA remote sensing data (Sentinel-2A). LiDAR based Digital Elevation Model processed by CESBIO for ECOPOTENTIAL. Data processing by UBT for ECOPOTENTIAL.

Ⓑ Special habitat for endemic species

Introduced species such as goats, rabbits and exotic plants threaten La Palma’s biodiversity. Since mammalian herbivores were not present until recently, local plants have no means to protect themselves, such as thorns or a bitter taste. Thus, they are an easy meal and can be heavily consumed by hungry mouths.

The dragon tree (*Dracaena drago*) is an iconic species of the Canary islands. ©CB

Kleinia neriifolia growing on lava in La Palma, Canary Islands. ©TR

As a relict ecosystem from the Tertiary period, the Laurel Forest is adapted to constant humidity. ©CB

Ⓒ Earth observation to access remote areas

Large parts of the island are simply inaccessible and unfavourable for human settlements due to steepness and unstable rocky substrates. This restriction avoids precise mapping and field work. Sophisticated remote sensing and modelling approaches are required to study these areas. Under the ECOPOTENTIAL project, inaccessible areas, threats and disturbances are being studied with the help of Earth observations. Satellite imagery is used to study the health of ecosystems and how they change over time. The extent and intensity of forest fires can also be recorded. The results from this work are being shared with the local managers and used for capacity-building in scientific field courses.

Many areas of the island are steep and inaccessible. Earth observation data can help to access them. ©DC

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain (*)
energy production
timber
wild land meat (*)
wild non-meat food (*)
fisheries
farmed sea food
(*) only in Natura 2000 sites

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
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pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

Lake Ohrid and Prespa

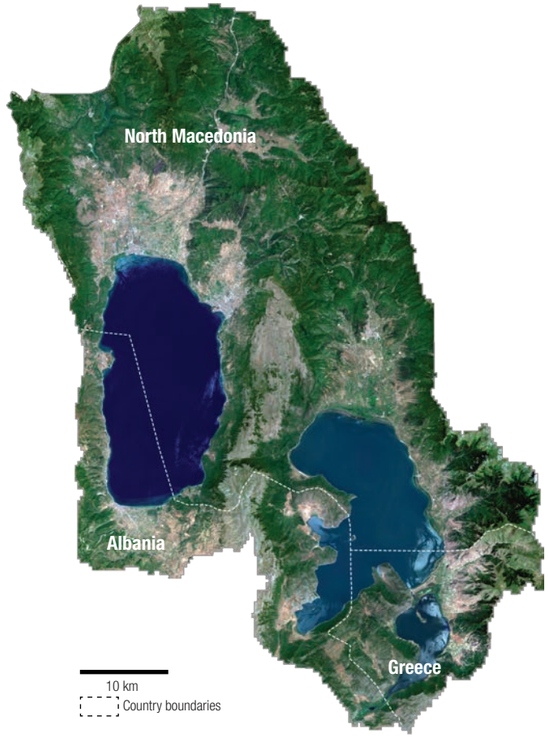
Physical, chemical and biological water properties are essential for characterising lakes' water quality, and satellite images can support their monitoring.

Formed between 1.3 and 1.9 million years ago, during the Pleistocene epoch, Lake Ohrid and Prespa are among the most ancient lakes in the world. These lakes never froze during the last Ice Age and were mostly isolated from other lakes, which led to their high biodiversity, including many native (endemic) species.

Ⓐ Threats and pressures

Currently, these lakes and the ecosystems in and around them are being pressured by human activities including tourism, overfishing, the introduction of alien species, rapid urbanization, water uptake, land-use intensification, pollution, eutrophication and climate change. Their transboundary location on the border between Albania, North Macedonia and Greece also poses several management challenges.

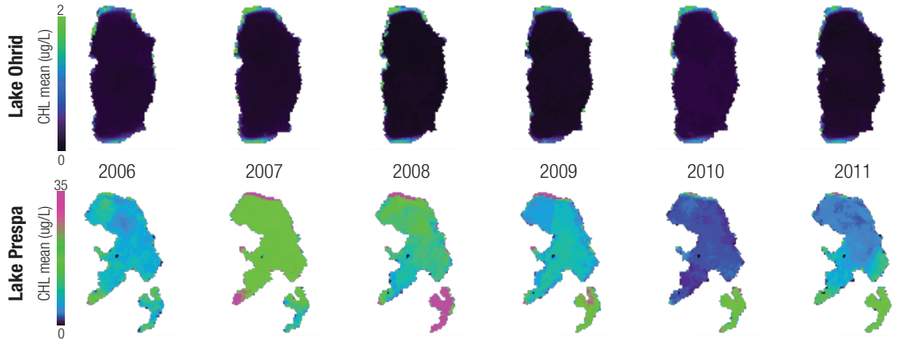
The landscape of Lake Ohrid. ©PBO



Sentinel-2A 2017-09-11 (True colour) image of the Lake Ohrid (to the west) and Lake Prespa and the Small Prespa Lake (to the east). Produced from ESA remote sensing data (Sentinel-2A).

Ⓑ Monitoring lake properties through Earth observation

Lake Ohrid is experiencing an increase of nutrients in many near-shore areas, which is causing an increase in algal growth. This growth, the urbanisation of the shoreline, the increase of disturbances due to the presence of tourists and the water level fluctuations, are the causes of the displacement of the nesting ground of the Ohrid trout (*Salmo letnica*) to greater depths. The lake is also at risk of a lower concentration of dissolved oxygen, which may reduce the diversity of the fauna living at the bottom of the lake. Data are available on the physical, chemical and biological properties of the water of both lakes. The high spatial resolution of satellite images, in turn, enables water quality and hydrological parameters such as chlorophyll concentration, transparency, seasonal changes, surface currents and surface area to be assessed across the whole lake area. Satellite images can also be used to monitor land-cover, land-use and vegetation change, allowing scientists to understand how changes on land affect the lake, and vice versa.



Envisat MERIS time series (2006-2011) of estimated average chlorophyll *a* concentrations in July. Chlorophyll *a* is used to estimate phytoplankton biomass; a high concentration indicates poor water quality. Images courtesy of Petra Philipson / H2020 SWOS project.

The ECOPOTENTIAL project uses in-situ and remote sensing data to assess the properties of the lake waters and of the habitat of endemic species. A simple ecological model will help evaluate the sensitivity of phytoplankton, zooplankton and fish to the changing conditions.

AL GR MK

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
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fisheries
farmed sea food

Regulating

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Cultural

recreation
education
research
aesthetic quality
spiritual significance

Peneda-Gerês National Park

PT

Grasslands and their biodiversity are among the highest conservation priorities in the park. Monitoring and management are essential to success.

Established in 1971, Peneda-Gerês is the only national park in Portugal. Its mountain range is part of the Gerês-Xurés transboundary Biosphere Reserve and the Natura 2000 network. Covering 70,000 hectares, the park hosts more than 800 native plant species as well as an outstanding array of Portugal's indigenous fauna.

Ⓐ Species richness: invaluable for sustaining ecosystem services

For centuries the land was managed under a mixed farming and pastoral system, which maintained high levels of landscape and species diversity. However, the gradual collapse of this rural way of life has brought profound changes in land-use patterns, and has impacted the extent and status of various habitat types. Perennial grasslands – highly valued for sustaining important ecosystem services such as cattle raising, soil protection and water regulation, and for their scenic beauty – are among those under highest pressure.

The Gerês lily (*Iris boissieri*) is an Iberian endemic and one of the more than 800 native plant species of the Peneda-Gerês National Park. ©ADERE Peneda-Gerês

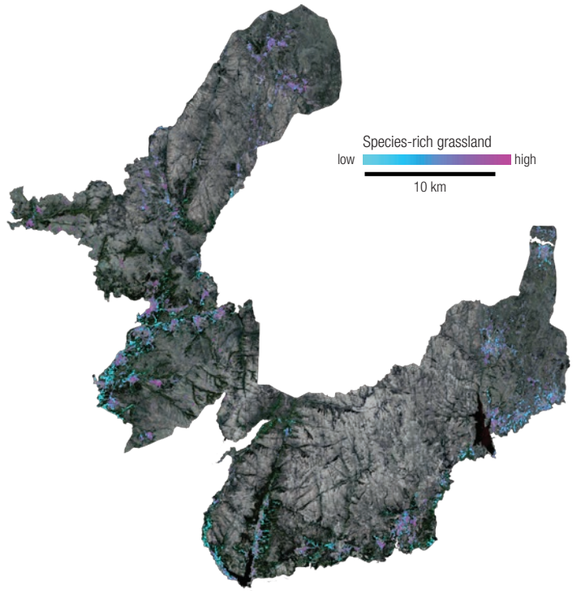
Little horse called "Garrano", a native breed living in the wild. In the front, the common gorse plant (*Ulex europaeus*). ©ADERE Peneda-Gerês

Upper-land grasslands provide resources to wildlife in the Peneda-Gerês National Park. Species-rich grasslands are among the most valued elements of this natural heritage. ©ADERE Peneda-Gerês

Ⓑ Monitoring perennial grasslands

High plant diversity in the grasslands is very important to ensure that these habitats function adequately. For decades, these grasslands have been gradually abandoned and encroached by scrub and woodland, increasing their susceptibility to fire and invasion by non-native species. To address this decline, park managers need to assess the distribution, status and connectivity of species-rich grasslands, and adapt management strategies accordingly.

The ECOPOTENTIAL project is addressing this challenge based on a dual grassland-detection and biodiversity modelling approach. Earth observation products are used to produce a time series of grassland habitat maps based on spectral properties of actively managed grasslands. Data on plant diversity collected in the field are used to develop a biodiversity model that assigns a predicted value of plant species richness to each mapped grassland. This allows park managers to identify and actively manage biodiverse grasslands, which hold high conservation priority in the EU (namely under the Habitats Directive). This approach can also track changes over time and anticipate future shifts under global change.



Map of the distribution of the species richness in the grasslands of Peneda-Gerês National Park, obtained from the combination of habitat detection and generalized linear modelling with Sentinel-2 (April and july 2016) data forcing. Produced from ESA remote sensing data (Sentinel-2A). Processed by António Monteiro, ICETA, CIBIO-InBIO, Portugal for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
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Cultural

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aesthetic quality
spiritual significance

Réunion

FR

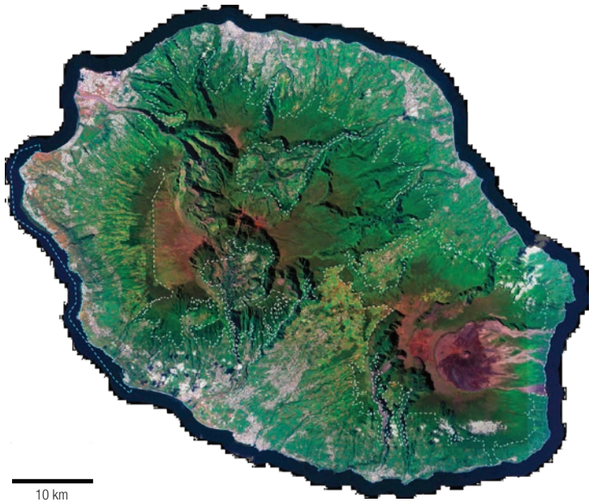
Mapping ecosystems on the volcanoes, monitoring ecological land cover, and water cycle research is all possible through Earth observation.

The volcanic island of Réunion is a French overseas department located in the warm Indian Ocean, east of Madagascar. It is home to one of the most active volcanoes in the world, Piton de la Fournaise, a UNESCO World Heritage Site since 2010.

Ⓐ The island's landscape: shaped by volcanic activity

The cycle of rock creation and destruction is very evident on Réunion, and starts when new rocks are formed by volcanic activity. Over time the lava fields are colonized by plants, the roots breaking up the rocks and together with rain, wind and sunshine starting the process of erosion. This cycle constantly modifies the landscape, creating and taking away niches for species to colonize.
This pronounced and iconic topography, which reaches up to 3,070 meters above sea level, therefore supports a variety of ecosystems with very high biodiversity. From the summit regions with sub-alpine shrubland and lush forests along their slopes, the land drops to coastal lowlands, where cultivated land and urban areas are found. Marine habitats that include coral reefs, rocky coasts and soft bottom sediments are found around the island.

Coral reef lagoon on the west coast of Réunion Island. ©AL



Spot 6 2016-04-08 image from Réunion island. From the active volcano and a summit peak at 3070 metres above sea level, down to the coral reefs along the urban west coast, Réunion Island supports a high diversity of natural and anthropogenic landscapes. © Kalideos databases – CNES, distribution Airbus D.S. All rights reserved.

Ⓑ Monitoring volcano ecosystems

The arrival of humans on the island 350 years ago led to the massive extinction of local biodiversity and the introduction of non-native species, which continue to transform native habitats. Over the last three decades, La Réunion has experienced rapid land-use changes and intensification of human activities, fuelled by population growth and economic development.

Today, about half of the 230 native (endemic) species are endangered. To protect them and the ecosystems in which they live, the Réunion National Park covers about 42 per cent of the island, concentrated in the mountainous interior. Most of the fringing coral reefs located along the western and southern coast are protected within the Réserve Naturelle Nationale Marine de La Réunion.

Upland agricultural and natural landscape of Réunion Island. ©JFB

ECOPOTENTIAL focuses on ecological land-cover, water cycle research and monitoring of protected areas on Réunion. Earth observation allows scientists to map the ecosystems on the volcanoes, the land-use changes and how this influences ecosystem services. The results will inform terrestrial and marine spatial planning decision-making to maintain Réunion's unique beauty and the quality of human life for generations to come.

ECOSYSTEM SERVICES

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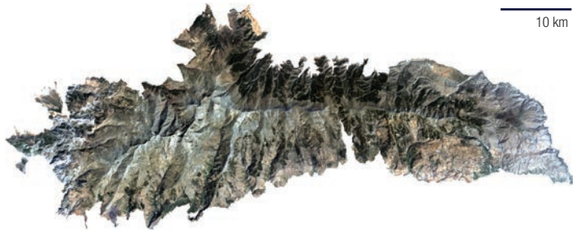
Sierra Nevada National Park

This high mountain national park has more than 3000 km of ancient irrigation channels from the 4th century AD that determine its natural landscape.

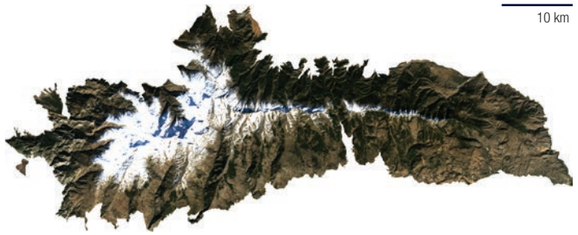
Sierra Nevada National Park is a high mountain range (reaching 3,482 m.a.l.s.) located in Southern Spain, which covers more than 2,000 km^2. It is considered one of the most important biodiversity hotspot in the Mediterranean region. The mountain range, which has several legal protections (Biosphere Reserve, Natura 2,000 and National Park), is surrounded by pastures and crops that provide services to more than 90,000 inhabitants who live inside the protected area.

Ⓐ Monitoring snow cover

Winter precipitation in the form of snow is typical in the park. The behaviour of the snow is extremely variable throughout the years specially concerning melting cycles and evaporation. When snow melts in spring, water reaches mountain streams and percolates to recharge aquifers.



USGS/NASA Landsat 5 TM 1985-09-15 (True Colour). Processed by UAB for ECOPOTENTIAL.



USGS/NASA Landsat 5 TM 2009-12-06 (True Colour). The top of the mountains are covered by snow. Processed by UAB for ECOPOTENTIAL.

Mountain stream ©UM

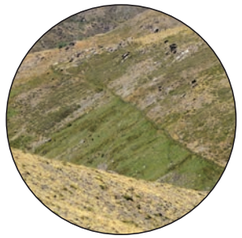
Ⓑ Ancient irrigation channels: a source of life

From the ninth century AD onwards, Muslim settlers built more than 3,000 km of irrigation channels on the mountain slopes. Many irrigation channels divert water from the springs and streams at higher altitudes and deliver it to the crops, grasslands and forests downhill. This process slows down the hydrological cycle, making good use of the water resources.

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.

Most of the channels are hand-made using stones and mud collected in site. This way of construction makes them partially permeable to water, allowing leaking and watering of downhill pastures. ©LD

Some irrigation channels collect water from the springs and streams by the summits and deliver it to the crops, grasslands and forests downhill. This process slows down the hydrological cycle in the mountain.©JMB



Some of the evident effects of the watering provided by irrigation channels can be quantified using remote sensing information. The pastures down of the channel ((green) are more productive than the ones up (red). ©

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Swiss National Park

Comparing protected areas to areas managed for agriculture and tourism in the Swiss Alps enables the effects of human interventions to be better understood.

The Swiss National Park was established in 1914 as the first national park in the Alps, with the aim of minimizing human disturbance and letting natural processes take their course. Today, the park covers an area of 170 km^2, consisting of forests (28%), alpine meadows (21%), rock and scree. Since no human interventions are allowed, it offers a perfect opportunity to observe the transition from a managed landscape to wilderness, and to monitor the effects of climate change.

Ⓐ Mountain ecosystem: source of services

For centuries, mountain ecosystems in the Alps have provided essential services such as food, timber and protection from natural hazards (e.g. avalanches, landslides), enabling mountain societies to thrive in these marginal environments. Former human activities exploiting such services left visible marks characterizing today's protected landscape. This unique environment allows to research the ensuing natural processes and also offer many opportunities for recreation, provide habitats to many rare and charismatic species, and contribute to climate regulation.

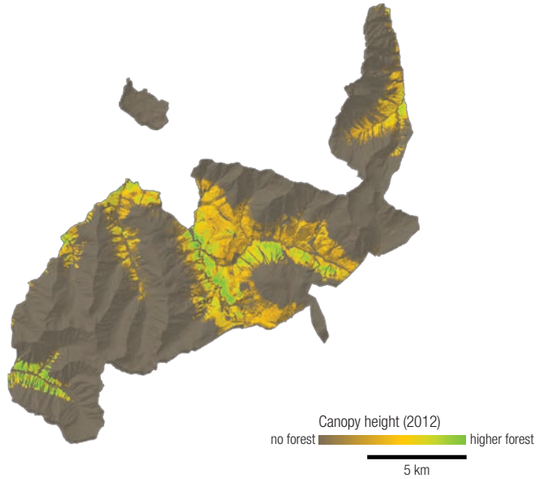
A survey of mountain flora at the summit of Munt Buffalora. Research is one of the main ecosytem services of the area. ©SNP

Hikers walk along the lakes of Macun. Although subject to strict regulations, around 150,000 people visit the park every year. ©SNP

Ungulates such as chamois (*Rupicapra rupicapra*) (pictured), red deer (*Cervus elaphus*), and ibex (*Capra ibex*) occur in high densities in the Park. ©SNP

Ⓑ Mapping ecosystem structure and services

Alpine communities depend on ecosystem services, such as protection from natural hazards, and people look for wilderness, wildlife and scenic beauty in protected areas such as the Swiss National Park. The ecosystems that provide these services are affected by changes in land use and climate, which also affect the services they provide. For example, more frequent disturbances may reduce carbon storage in the forests and their capacity to prevent avalanches. In ECOPOTENTIAL, we are using modelling to better understand the demand and supply of mountain ecosystem services. For example, we use a combination of airborne and satellite imagery to distinguish different forest structures and tree species. Combined with data on houses and infrastructure, this information allows us to map the forests that protect people from avalanches. As forest structures change, the maps can be updated with new Earth observation data.



Canopy Height vegetation model product (2012) derived from stereo image matching Leica ADS, which helps to distinguish different forest structures. Brown colour indicates non-forested areas, while green colour indicates the areas of greatest height of the trees within the park boundaries. Original data from WSL. Produced by CESBIO for ECOPOTENTIAL.

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Arid Ecosystems

Zin Valley - Har Ha Negev National Park ©CD

Har HaNegev National Park

Supporting social development while protecting the integrity and biodiversity of the area is a major challenge available to Earth observation.

Located in the heart of the Negev Desert in Israel, the Negev Highlands ("Har HaNegev") cover an area of 445 km^2. This protected area includes a national park, the UNESCO World Heritage Incense Route, and several national nature reserves established for their unique flora, fauna, water resources, geological features and archaeological values. The area also contains two urban settlements, several single-family agricultural farms, Bedouin settlements, as well as military bases and training areas.

Ⓐ Human-environment interactions: protection plays a key role

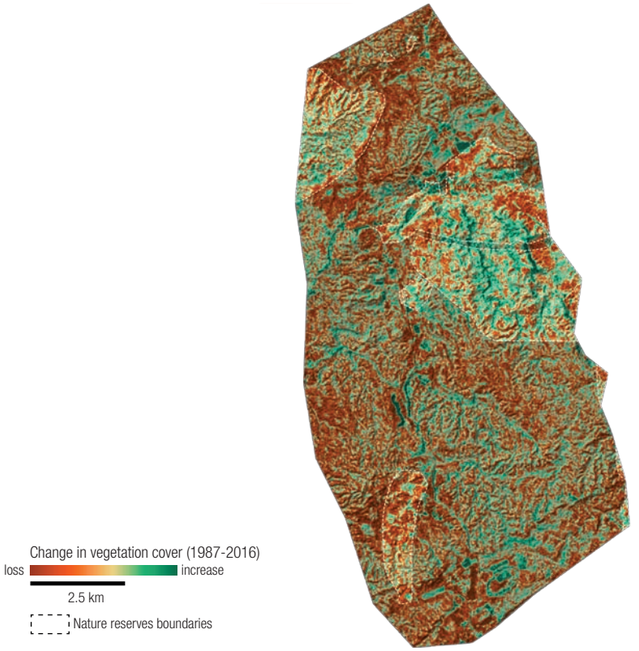
The Negev is important due to its ecological conservation on one side, and its economic and residential potential on the other side. Currently, the challenge is to support development while protecting its ecological integrity and biodiversity. Since the area has been populated and used intensively for at least the past 2,500 years, studying historical human–environment interactions can provide insights to guide future development. For example, the Nabataeans, who established the city of Avdat in 300 B.C.E. as a station on the Incense Route, facilitated desert agriculture by building wide-scale terracing to capture run-off and soil.

WorldView-2 image of the ancient desert city of Avdat (2010-07-15). Ancient agricultural terraces can be identified at the plain of the mountain. DigitalGlobe (image created with ShowMySite): [WorldView 02] © [2010] DigitalGlobe, Inc. Data provided in the framework of the ESA Earthnet TPM Programme, through the ESA EOhopS project managed by CloudEO.

Rock terraces have been built across the wadis to capture runoff and to generate gradual deposition of soil. ©SG

Ⓑ Monitoring ecosystem conservation threats

Many of these landscape modifications have endured and continue to affect ecosystem flows, productivity and species diversity. Some of the practices find current analogies in the grazing and rain-fed agriculture of the Bedouin communities or in the irrigated agriculture of single-family farms. The ECOPOTENTIAL project uses multiple methodologies to study human–environment interactions in the protected area, including remote sensing, biodiversity surveys and social research. These various research strands will be integrated to support policy-relevant directives for future development and conservation.



USGS/NASA Landsat derived product showing change in the vegetation cover between years 1987 and 2016 product in the Har HaNegev. Most of the nature reserves (seen within the dotted lines) have experienced a positive change in vegetation rehabilitation, while other areas are characterized by vegetation degradation. Processed by Ben Gurion University, Noa Ohana-Levi, for ECOPOTENTIAL.

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Kruger National Park

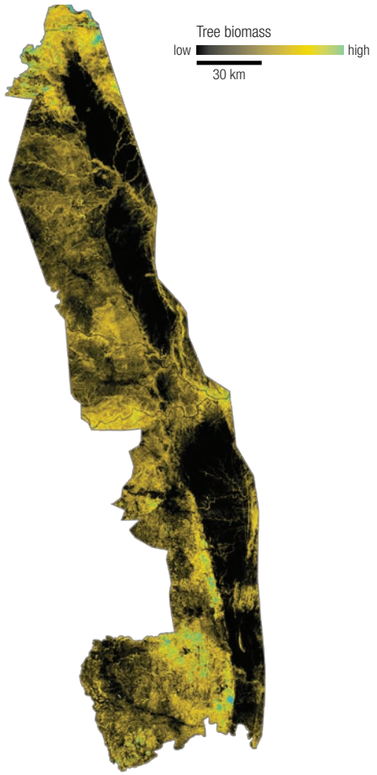
Earth observation is essential for mapping and monitoring grasslands and trees and helps managers to maintain the park's rich biodiversity.

Kruger National Park in north-eastern South Africa is the country's largest national park which extends over 2 million hectares. This savanna, a unique ecosystem, has an impressive number of trees, birds, insects and mammals. While the park is still largely an intact and natural landscape, it does need to be managed. Among others activities, managers control herbivore populations and their movements to insure the balance between trees and grasses, using Earth observation to monitor the savanna.

Ⓐ Development of Earth observation monitoring tools

Kruger National Park is a savanna, which is characterized by a mixture of grasses and trees, neither of which ever manages to totally outcompete the other. Earth observation is being used to map and monitor grasses and trees, allowing managers to understand the pattern of changes over time.

The iconic baobab trees are found in the north of Kruger National Park. ©IS



Sentinel-1 derived biomass model used to measure the woody biomass in the Kruger National Park. Yellow, green and light blue areas indicate locations with more woody vegetation. Black areas represent open areas with less vegetation. Produced from ESA remote sensing data (Sentinel-1). Processed by CSIR for ECOPOTENTIAL.

Ⓑ Ensuring the park's rich biodiversity

Droughts, fires and herbivores (especially elephants) are nature's way of maintaining this patchwork of trees and grasses.

Elephants are one of the most charismatic species found in Kruger, and play an important role in regulating the ecosystem. In recent years, elephant numbers have increased in the park. ©PB

Bushfires are a common, natural and important occurrence in savannas. Both lightning and management fires create a patchwork of burnt and unburnt areas ©CG

Drought is also a threat for vegetation in this region where water is a limiting factor. ©SG

Earth observation also helps managers to understand the impact of elephant increasing population on the tall trees and the encroachment of small bushes on grassland. For example, the park's managers influence fire regimes and manage water supplies and fences, which affect herbivore populations and movements. Management actions should, however, be careful in providing either trees or grasses a competitive advantage, since it is precisely this mixture that ensures the park's rich diversity in plants and animals. In order to monitor whether this mixture is being maintained over millions of hectares, projects such as ECOPOTENTIAL are using Earth observation technology as the 'eye in the sky'. This technology is helping researchers to understand the pattern of changes over time and feed this information back to the park managers.

WorldView 02 image of the managed Nwaswitshumbe enclosure (2013-05-09) which helps researchers to understand the effect of herbivores on vegetation. DigitalGlobe (image created with ShowMySite): [WorldView 02 Kruger] © [2013] DigitalGlobe, Inc. Data provided in the framework of the ESA Earthnet TPM Programme, through the ESA EOhopS project managed by CloudEO.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
erosion prevention
pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

Montados

PT

Regular assessment to improve multifunctional management of montados by Earth observation promotes structural diversity of this natural value wood-pasture system.

Montado (*dehesa* in Spanish) is a traditional woodpasture system where cork oaks (*Quercus suber)* and holm oaks (*Quercus rotundifolia*) 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. In Portugal, Montados are mainly distributed in the southern half of the country where the climate is Mediterranean.

Ⓐ Provisioning and regulating services: an asset of montados

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 frequent droughts and warmer summers, soil degradation from overgrazing and tillage (for crop seeding and shrub control), pests and disease. The current lack of regeneration and the death of adult trees are of serious concern and may lead to an eventual loss of montados and their replacement by shrubland.

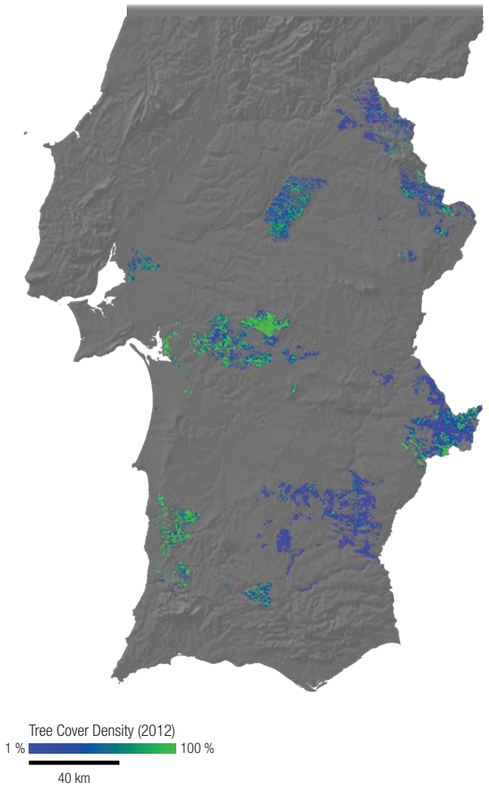
Montados are High Natural Value wood-pasture systems characteristic of the Mediterranean basin. Cork oaks (*Quercus suber*) and holm oaks (*Q. rotundifolia*) are the dominant trees, forming pure or mixed stands with a savanna type structure. ©RC

Livestock production in pastures is one source of income provided by Montados. However, excessive livestock densities and overgrazing currently threaten this traditional wood-pasture system. ©TSA

It takes 25 years for a cork oak (*Quercus suber*) to be ready for cork extraction. From that point on, cork is harvested every 9 to 12 years. It is the most important forest product from Montados. ©MJ

Ⓑ Assessing age structure of montados through Earth observation

The correct management of soil, grazing and the overall habitat can counteract these threats. For example, protecting and restoring soil condition is central to improving tree health. Measures to ensure the survival of juvenile trees into adulthood are also needed to ensure that montados thrive in the long term. The ECOPOTENTIAL project is using indicators, such as Tree Cover Density or Leaf Area Index, to monitor changes in tree cover and to track tree mortality and weakening. This information, combined with data from the field, 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 montados can be regularly assessed using Earth observation, farmers can be better advised, and management practices can be continuously improved in a quick and expedite manner.



Tree cover density map (2012) within Montados listed under the Natura 2000 Sites of Community Importance (SIC) of the Alentejo region, southern Portugal. Produced by Copernicus Land Monitoring Service with funding from the European Union. Post-processed by CESBIO-UPS for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
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pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

Murgia Alta

IT

Human pressure has accelerated the process of habitat fragmentation in the area, endangering its balance. Earth observation helps in monitoring habitat changes.

Murgia Alta is a Natura 2000 site and a National Park spanning over 125,880 ha. The site, located in Southern Italy, is one of the most important European areas for the conservation of semi-natural dry grasslands, such as "*Eastern sub-mediterranean dry grasslands (Scorzoneretalia villosae)*" and "*Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea*" of the Habitat Directive.

Ⓐ Monitoring the transformation of natural grasslands

The conversion of grasslands and natural pastures into croplands, through the removal of stones, is the most important pressure that transforms the heterogeneous semi-natural landscape into a monotonous extension of crushed stones. This activity causes the loss of such ecosystems, especially during the most extreme weather events. Moreover, the illegal dumping of waste and toxic mud on transformed areas is causing heavy metal contamination of soils and local aquifers. The ECOPOTENTIAL project is monitoring these changes by producing and comparing regular grassland habitat maps based on spectral properties of the natural and actively managed grasslands. Such analysis allows park managers to identify and actively manage biodiverse grasslands.

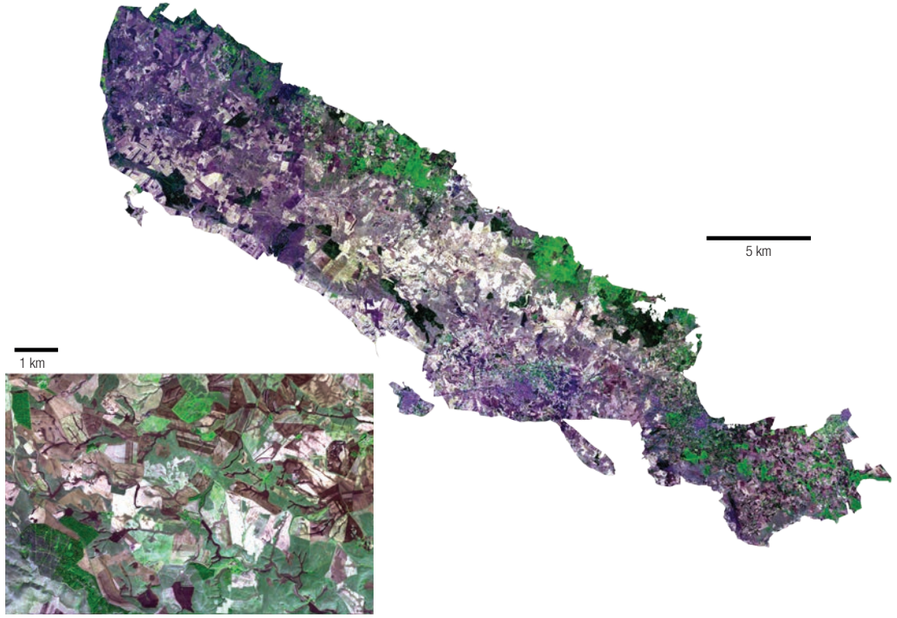
A semi-natural pasture used for sheep-farming. ©LM

Rocks are extracted and removed from the soil before the final graining procedure. ©LM

Arable land created through the process of soil graining. Most of this arable land is used for cereal crops. ©LM

Ⓑ Monitoring landscape dynamics for biodiversity protection

The dynamic of landscape has evolved through a mix of anthropogenic and natural processes over long periods of time. However, the gradual anthropogenic pressures have directly impacted the ecosystem extent and its quality, originating grassland fragmentation and woody encroachment, among others. The park protects a significant range of grassland ecosystem biodiversity, but species such as the Lesser kestrel (*Falco naumanni*) are among those under pressure.



Sentinel-2 image 2015-08-07 (False colour) of Murgia Alta. In the close-up: WorldView-2 2011-10-05. Rocky natural-grassland patches, in light green, are fragmented by cultivated areas appearing in brown and white colours after ploughing. Bright cultivated patches belongs to fields where farmers grained rocks and stones belonging to natural grasslands in the past to increase cultivated areas and cereals production. Woodlands appear in dark green. Processed by CNR for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

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spiritual significance

Samaria National Park

GR

Algorithms, Earth observation products and field data are essential to understand and support the conservation of the habitat of the endemic and rare Cretan lizard.

Samaria National Park is located on the White Mountains massif at the Southwest part of Crete, one of the largest islands in the Mediterranean Sea and a popular holiday destination. The area is characterized by high mountains (more than 50 peaks over 2,000 m above sea level) and many scenic gorges. The terrestrial biodiversity is unique, with more than 1,000 species of both flora and fauna and many endemic species. Designated National Park in 1962, it is also a Natura 2000 site, a UNESCO Biosphere Reserve (MAB) and a Landscape of Outstanding Beauty.

Ⓐ Protecting Mediterranean mountain biodiversity

The White Mountains range, the largest massif on the island, has many scenic gorges, as well as snow that lasts up to May on its subalpine zones. The area is also characterised by forests of pine and cypress species, pastoral areas, temporal cultivations and shrublands. Therefore, the park protects an extensive range of Mediterranean mountain biodiversity, including endemic species that can only be found on certain cliffs or peaks.

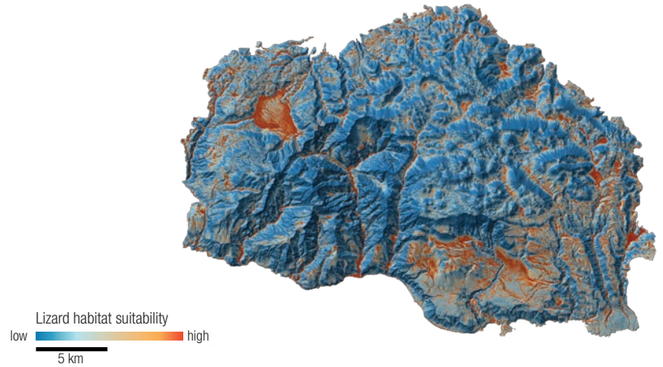
The alpine zone of the White Mountains, viewed from Roussies. ©AT

A bird´s eye view of the Aradaina gorge. ©DP

The Samaria gorge takes its name from the village located in the middle of the gorge, here pictured. ©DP

Ⓑ Habitat of endemic lizards

The Samaria National Park is home to six species of lizards, including the Cretan lizard (*Podarcis cretensis*) which is endemic to western Crete. Within the park, ECOPOTENTIAL is using Earth observations to better understand and predict the preferred habitat of Cretan lizards, including using Digital Surface Models to provide a 3D representation of the terrain. A mathematical model takes into account a range of factors such as solar radiation, wind exposure and terrain roughness to predict the spatial distribution of lizards. These are combined with actual recordings of lizard locations to test and refine the model. By feeding climate projections into the model, it can also be used to predict where lizards might be found in the future.



Map of the Cretan lizard habitat suitability obtained from the combination of algorithms, Earth observation products and field data. Processed by FORTH for ECOPOTENTIAL.

Knowing which areas are and will be important for the lizards is essential for targeted conservation of this endemic species. Human activities that threaten their habitats can be managed to best preserve the ecological integrity of the national park, which brings a large number of visitors and income for the local economy.

The endemic Cretan lizard, *Podarcis cretensis* ©DP

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
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wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
erosion prevention
pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

Coastal and Marine Ecosystems

The Camargue Wetlands ©SG

Curonian Lagoon

LT RU

Monitoring processes such as changes in waterbird habitats and agricultural activities is a challenge to be overcome through Earth observation data analysis.

The Curonian Lagoon, separated from the Baltic Sea by the Curonian Split, is Europe´s largest lagoon and is shared between Lithuania and the Russian Federation's Kaliningrad Oblast. The lagoon and its surrounding region host very diverse environments, including marine waters, the brackish lagoon, the freshwater Nemunas delta, sandy dunes, seasonally flooded meadows, rivers, lakes, fishponds and swamp forests.

Ⓐ A protected area for waterfowl conservation

The lagoon and especially the Nemunas delta and its wetlands are considered globally important sites for waterfowl conservation. They serve as one of the most significant staging areas for geese, ducks, swans and waders on their migration route from Western Europe to the Arctic.

Grey heron (*Ardea cinerea*) and great cormorant (*Phalacrocorax carbo*). Great cormorant receives much scientific attention for its assumed competition with fishermen. ©VZ

Reed (*Phragmites australis*) beds in the lagoon. Only part of the territory covered by reed is available for the commercial harvesting as reed beds also constitute important habitats for birds. ©TRU

Sentinel-2 mosaic of 2017-08-16 images (True colour) showing the entire region of the Curonian Lagoon and the Nemunas Delta. Produced from ESA remote sensing data (Sentinel-2). Image processed for ECOPOTENTIAL.

Ⓑ Monitoring flood dynamics

Flooding is a regular occurrence during spring in the Curonian Lagoon, when vast areas of the Nemunas delta can be placed under water for weeks. While high levels of flooding can be hazardous for local communities and damaging to their economic activities, they can bring greater fish spawning success compared to medium or low floods. Flooding also leaves behind fresh, nutritious grass sprouts for birds to feed on before migrating and breeding. As the water levels drop, the meadows become important breeding habitats for critically endangered bird species such as the great snipe, aquatic warbler and several species of terns and waders.

Detail of Sentinel-2 (2017-08-16 True colour) displaying the evolving nature of the coastline due to changing water levels. The orange line shows the coastline during low tide (2016-10-26) while the white line shows the coastline during high tide (2016-12-01). Produced from ESA remote sensing data (Sentinel-2). Image processed for ECOPOTENTIAL.

Earth observation tools can be used to monitor a number of important processes in the lagoon and its surrounding region. As one of the richest fishing areas in the Baltic Sea region, field observations and analysis of hydroperiod and flood distribution obtained from satellite images from ECOPOTENTIAL can play an important role in modelling the spawning and recruitment of commercial fish species. Analysis of flood levels and distribution through Earth observation can also detect changes in waterbird habitats and agricultural activities.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat (*)
agriculture, grain (*)
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food
(*) only in Nemunas delta

Regulating

life cycle & habitat protection (*)
flood prevention (*)
carbon sequestration
water treatment
erosion prevention (*)
pollination
pest control & disease control
(*) only in Nemunas delta

Cultural

recreation
education
research
aesthetic quality
spiritual significance

Danube Delta

RO
UA

The development of monitoring tools to support management and conservation decisions is essential to preserve the biodiversity and cultural services of this park.

At its mouth, the Danube river forms a huge delta covering over 5,000 km². Shared between Romania (86 %) and Ukraine (14 %), it creates a complex landscape that includes freshwater ecosystems (canals, shallow lakes, and wetlands), flood plains, alluvial forests, reed beds, lagoons and coastal areas. The delta is still growing in size, spreading seaward at an annual rate of 24 to 30 metres.

Ⓐ Biodiversity: the main attraction of the delta that needs to be protected

More than 300 bird species (including 160 migratory), 80 fish species and almost 1,000 plant species can be found in the delta. The entire area is a UNESCO World Heritage Site, UNESCO Biosphere Reserve and Ramsar Site, as well as part of the Natura 2000 network. The delta's rich biodiversity, cultural heritage and international reputation attract 150,000 tourists every year, many of whom are fishermen, birdwatchers and walkers enjoying the beauty of the water-dominated landscapes and the Black Sea coast. Tourism is one of the most important sources of income for the local population and, provided that it is sustainable, can support nature conservation.

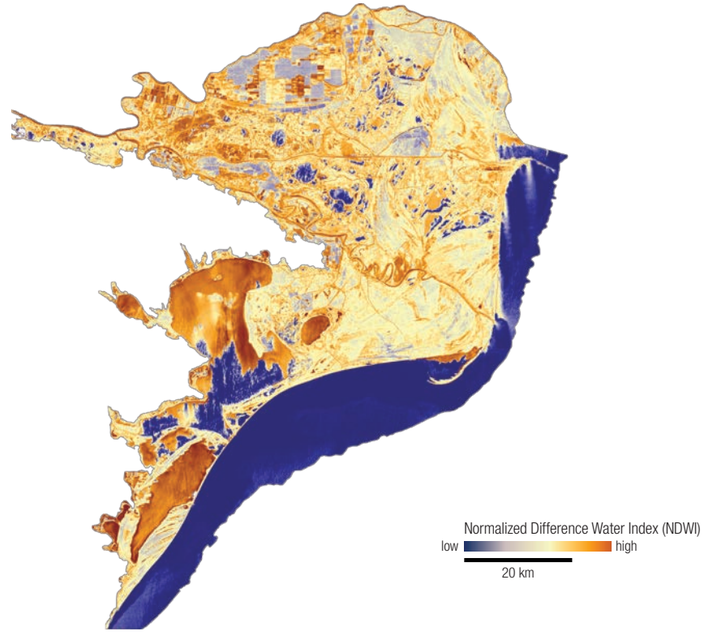
About half of the world great white pelican (*Pelecanus onocrotalus*) and over 60 % of the world's pygmy cormorants breed within the Danube Delta. ©ICS

White water lily (*Nymphaea alba*).

Reed harvesting and drying. Reed forms one of the largest compact areas covering 2,400 km².

Ⓑ Water quality: a challenge for Earth observation

The amount of nutrients transported by the Danube greatly affects the delta's productivity. A more productive aquatic ecosystem can sustain more fish, and therefore attract more recreational fishermen as well as more fish-eating birds, which in turn attract more birdwatchers, photographers and tourists. On the other hand, too large nutrient input can make these wetland and coastal ecosystems over-productive, resulting in algal blooms and therefore reducing their value and attractiveness.
The ECOPOTENTIAL project uses Earth observation and in-situ data to investigate how the indicators of water quality (chlorophyll, turbidity etc.) relate to the tourist presence, and thus to develop important monitoring tools to support management and conservation decisions.



USGS/NASA Landsat 8 OLI 2017-04-11 Normalized Difference Water Index (NDWI) product used to monitor the vegetation water content and to observe the dynamics of the vegetation. Image processed by UAB for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
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wild land meat
wild non-meat food
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Regulating

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Cultural

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aesthetic quality
spiritual significance

Doñana National Park

SP

Predicting and monitoring the responses of waterbirds to environmental drivers can be improved by mapping marsh water levels through Earth observation.

Doñana National Park contains one of the largest wetlands in western Europe, lying within the delta of the Guadalquivir River (south-west Spain). Covering over 110,000 hectares including dunes, marshes, temporary ponds, Mediterranean scrub and pine forests, the park is home to over 200 endemic and endangered species of plants and animals, many of which are associated with its aquatic habitats. Over 300 different species of birds can be sighted annually, including over 100 species that are directly dependent on the wetlands.

Ⓐ The hydroperiod: an important biodiversity factor

This remarkable waterbird diversity is the result of the variety of habitats and the dynamic changes that occur in Doñana. The size and depth of the wetlands vary remarkably from year to year, driven principally by varying rainfall. Wetland flooding starts from September onward. In late spring, evaporation becomes the most important factor influencing water levels, and most of the marshes are completely dry by the end of July. The different water depths, flood duration, chemical composition, vegetation cover and soil types lead to very diverse flora and fauna and create attractive landscapes for waterbirds and humans.

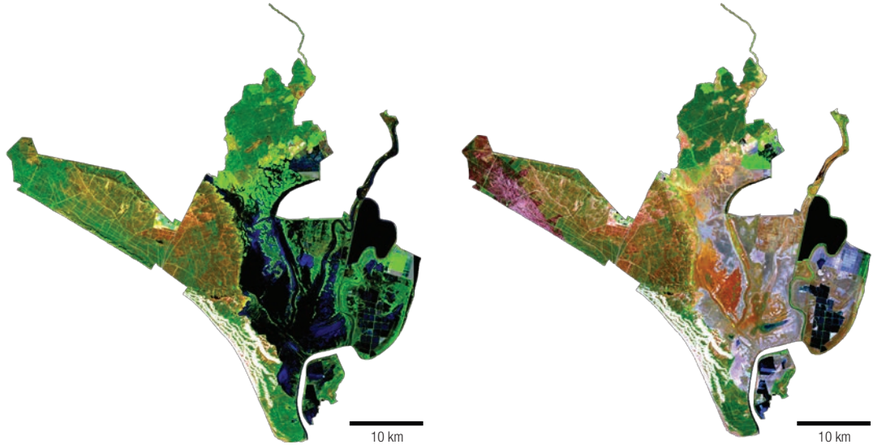
The increase in nutrients in water supplying Doñana wetlands causes their eutrophication. This process drastically changes water communities, e.g. floating plants, such as the alien floating fern *Azolla filiculoides*, which becomes more abundant. ©RRO

In terms of the cultural values and other ecosystem services provided by birds, Doñana is clearly critical for the survival of many migratory bird populations. Doñana attracts birdwatchers and other ecotourists from all over Europe and beyond. ©RRO

Marshlands and Marismeña cow, Reserva Biológica de Doñana, Almonte, Huelva. This highly polymorphic breed is the origin of several American races, including the Texas Longhorn. ©ER

Ⓑ Bird monitoring through Earth observation

The ECOPOTENTIAL project combines traditional bird monitoring data with Earth observation to gain a better understanding of how bird occurrence is related to wetland features. Variations in flooding are mapped and seasonal and inter-annual variations are monitored. Satellite images, correctly interpreted based on the knowledge gained from field data, are used for management purposes and to help conserve endangered species. Modifications in the wetland structure due to processes such as sedimentation or variable flooding are assessed in order to estimate the future impacts of climate change and the effects of implementing different management options.



Left: USGS/NASA Landsat 8 OLI 2016-12-23. Right: USGS/NASA Landsat 8 OLI 2017-08-04. (False colour). In December (left), the marsh is flooded. Areas of water in the marsh and ponds appear as black or dark blue. In August (right), the marshes have dried out and bare soil areas look gray. Large areas with dry helophyte vegetation in the central area have an orange colour. There are some flooded areas in the east corresponding to fish farm ponds. The area in the west that was burned during a forest fire in June 2017 shows a pink colour. Image processed by LAST-EBD for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
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energy production
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Cultural

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aesthetic quality
spiritual significance

Pelagos Sanctuary

IT MC FR

Monitoring individual animals from satellites is now possible thanks to very high resolution satellites, which help decision makers to improve management.

The Pelagos Sanctuary for Mediterranean Marine Mammals ™ is an international marine protected area (87,500 km^2) between Italy, Monaco and France. It was established in 2002 to protect significant feeding and breeding habitats for the cetacean populations. The major cetaceans living in that area are the fin whale (*Balaenoptera physalus*) and the striped dolphin (*Stenella coeruleoalba*).

Ⓐ Human pressure: a real threat for cetaceans

The Mediterranean Sea is home to many species of whales and dolphins, which now have to share their habitat with human activities: maritime transport, military exercises, oil and gas exploration, tourism, boating, recreational activities and commercial fishing. These activities are potentially harmful to whales and dolphins. For example, over-fishing leads to food scarcity and a high risk of entanglement in fishing gear, while oil and gas exploration induces high levels of underwater noise and pollution. However, the biggest concern comes from the risk of collisions with ships and boats. Understanding how, when and where whales and dolphins move across the Mediterranean Sea is therefore an important step towards implementing measures to protect these marine mammals.

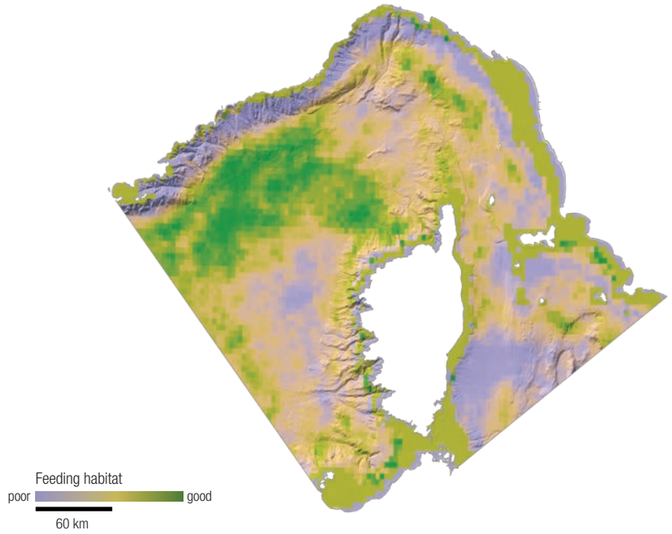
A striped dolphin (*Stenella coeruleoalba*) jumping out of the water. ©AL

A fin whale (*Balaenoptera physalus*) shows signs of injury around its dorsal fin. These are consistent with a vessel strike. ©TSP

Dead whale carried onto a ship bow after collision. ©SE

Ⓑ Monitoring individual animals from space

The ECOPOTENTIAL project is working to combine satellite imagery, in-situ observations and ecological modelling with information from whale-watching operators and shipping. The work is focused on the Pelagos Sanctuary for Mediterranean Marine Mammals™. Until a few years ago, monitoring individual animals from satellites was not even conceivable. In collaboration with the British Antarctic Survey, ECOPOTENTIAL is applying very high-resolution satellite imagery to find fin whales from space. This imagery is combined with ecological modelling, shipping traffic data and whale-watching activity zones to build a more complete picture of where whales are located and where the risks (e.g. from shipping) are greatest. This kind of information helps decision makers identify high-priority areas for both marine mammals and human activities.



Map of quality of feeding habitats for fin whales within the Pelagons Sanctuary (2003-2016). It is modelled from trends in ocean productivity based on chlorophyll levels. Data source: European Commission, DG Joint Research Centre, Directorate D – Sustainable Resources, Unit D.02 Water and Marine Resources, https://fishreg.jrc.ec.europa.eu/fish-habitat. Image processed for ECOPOTENTIAL.

ECOSYSTEM SERVICES

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The Camargue

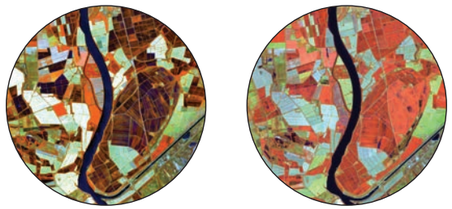
FR

Hydrological heterogeneity contributes to the park's overall biodiversity, but it also puts in jeopardy the ecosystem functioning, which must be monitored through Earth observation.

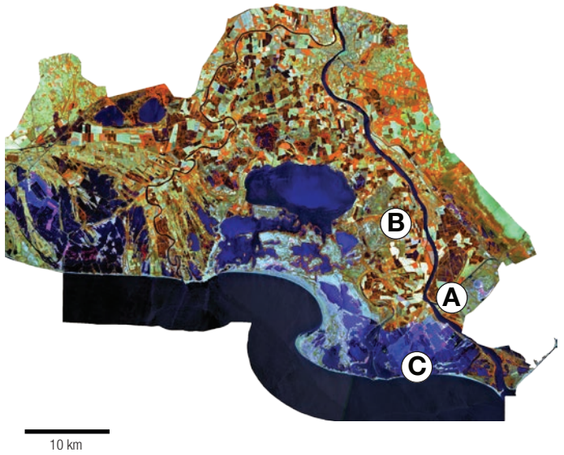
The Camargue is a delta formed by the Rhône River in southern France. This UNESCO Man and Biosphere Reserve covers 1,450 km^2 inland and 480 km^2 in the Mediterranean Sea. It contains many emblematic wetlands, including freshwater ponds, wet grasslands, reed beds, semi-permanent brackish marshes, temporary pools, salt marshes and lagoons. These wetlands are interspersed with agro-ecosystems dominated by rice paddy fields and saltworks.

Ⓐ Development of Earth observation monitoring tools

Monitoring the short and long-term dynamics within the Camargue is necessary to guide wetland management to ensure that wetlands' integrity and the services they provide are well preserved. ECOPOTENTIAL is providing Earth observation tools to routinely monitor the seasonal water dynamic of wetlands and changes in land cover, land use and crop types. Looking to the future, climate projections for 2050 and 2100 have been analysed to assess the potential impact of climate change on wetland hydrology. This information will be used to propose management and adaptation measures to the various wetland users.



Left: Sentinel-2A 2016-07-07 (False colour). Right: Sentinel-2A 2016-08-23. Flooded rice fields at the beginning of July (in dark blue) turn to green tillering rice fields by the end of August (red). Produced from ESA remote sensing data (Sentinel-2A). Image processed by CREAF for ECOPOTENTIAL.

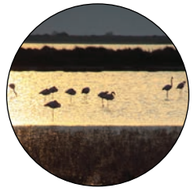


Sentinel-2A 2016-07-07 (False colour). Blue areas correspond to lagoons which mainly rely on salty water from the nearby Mediterranean Sea. Red and brown areas correspond to active agricultural fields while green areas correspond to bare soils. Produced from ESA remote sensing data (Sentinel-2A). Image processed by CREAF for ECOPOTENTIAL.

Ⓑ Irrigation channels: protection for biodiversity

A complex network of irrigation and drainage channels pumps about 730 million cubic metres of fresh water each year from the Rhône into the Camargue, to compensate for river embankments and avoid soil salinization. This water is mainly used in rice production but also helps to maintain or increase wetland-related ecosystem services such as ecotourism, nature conservation, wildfowl hunting, fishing, reed harvesting and cattle grazing.

Irrigation channel ©CD

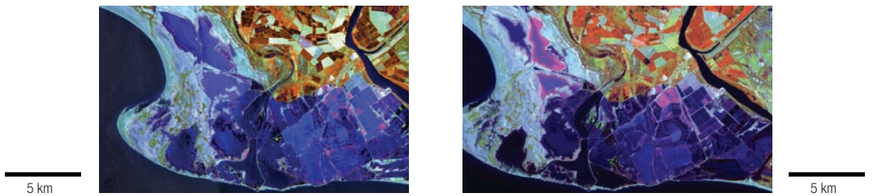


Greater flamingos (*Phoenicopterus roseus*) eating in the salt flats ©CD

Dragonflies have an aquatic larval stage and serve as good water quality indicators. ©PL

Ⓒ Salt flats flooding stages

In the south, 100 million cubic metres of seawater are pumped into lagoons each year for salt production. Flooding stages and salinity concentrations can be monitored through Earth observation. The challenge lies in maintaining the Camargue's diverse wetlands and services, while preserving its typical Mediterranean flora and fauna. The fragile balance between wet or dry, and fresh or saltwater ecosystems is threatened by climate change, which affects rainfall, river flow and sea level.



Left: Sentinel-2A 2016-07-07. Right: Sentinel-2A 2016-08-23 (False colour). Salt flats are flooded by the beginning of July (blue areas). By the end of August, water has evaporated and flooded fields have reduced their surface. The driest the salt flats, the more the salt accumulated (pink areas). Produced from ESA remote sensing data (Sentinel-2A). Image processed by CREAF for ECOPOTENTIAL.

ECOSYSTEM SERVICES

Provisioning

fresh water
genetic resources
agriculture, meat
agriculture, grain
energy production
timber
wild land meat
wild non-meat food
fisheries
farmed sea food

Regulating

life cycle & habitat protection
flood prevention
carbon sequestration
water treatment
erosion prevention
pollination
pest control & disease control

Cultural

recreation
education
research
aesthetic quality
spiritual significance

The Mediterranean Large Marine Ecosystem

Earth observation is a unique tool for monitoring the seawater conditions of the whole Mediterranean, which is necessary to promote its conservation.

The Mediterranean Sea is a Large Marine Ecosystem and the largest enclosed sea in the world. Its 46,000 km coastline spans many countries across three continents (Europe, Africa and Asia). Rich in marine life and other features, it is estimated to host between 4 per cent and 18 per cent of the planet's macroscopic marine organisms. It provides many valuable goods and ecosystem services to society, including coastal protection, food, tourism, recreational opportunities and many more.

Ⓐ Changing climate conditions: a threat for fish

The Mediterranean Sea's fish and other living resources supply the fishery and aquaculture sectors, which may be threatened by human activities, especially under changing climate conditions.

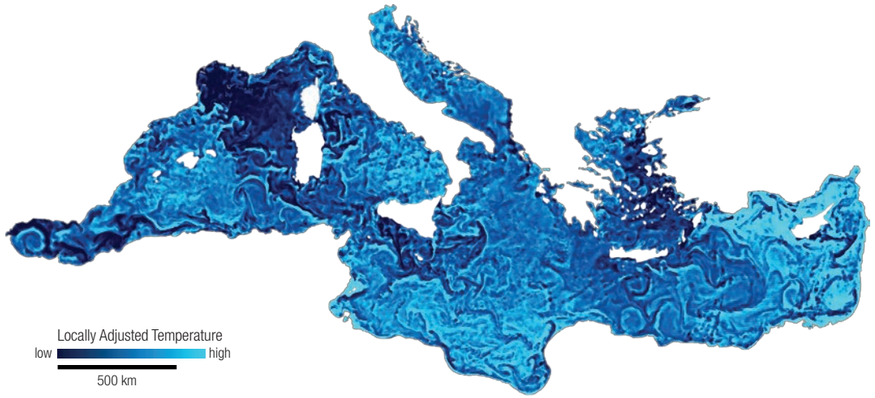
The red coral, *Corallium rubrum*, is found mainly in the Mediterranean Sea. ©JS

A school of juvenile rabbitfish (*Siganus rivulatus*), which is among the 100 worst invasive species in the Mediterranean.©DP

Ⓑ Monitoring seawater conditions through Earth observation

Monitoring seawater conditions is therefore of paramount importance for scientists and the Marine Protected Area managers, who are involved in the conservation of marine natural resources. For example, changes in seawater temperature affect the delivery of ecosystems services such as food provision, as seawater temperature influences the activity and health of fish, including their feeding, reproduction, movement and distribution.

Through the use of Earth observation (by examining over 12,000 images) and other tools, the ECOPOTENTIAL project team has observed that, over the past few decades, the Mediterranean Sea has become progressively warmer, which has favoured the establishment of invasive species. Also, an analysis of future scenarios indicates that, in the near future, the Mediterranean Sea will become progressively warmer, affecting the movement and distribution of fish and thereby generating new food-provision scenarios.



Water circulation patterns in the Mediterranean basin 2014-06-23 derived from the Sea Surface Temperature product from Copernicus Marine Environment Monitoring System. It contains modified Copernicus Marine Environment Monitoring System data produced with funding from the European Union. Produced by ISPRA for ECOPOTENTIAL.

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Wadden Sea

DE DK NL

Habitat mapping and food detection derived from Earth observation data is essential for modelling predictions of bird food sources.

The Wadden Sea is a highly productive estuarine area and one of the largest coastal wetlands in the world. A network of national protected areas spreading across the North Sea coastal areas of the Netherlands, Germany and Denmark exists to protect this remarkable area. Furthermore, the area as a whole constitutes a UNESCO World Heritage Site and is covered by the Natura 2000 network.

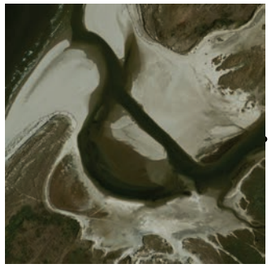
Ⓐ Wadden Sea: a biodiversity hotspot

The Wadden Sea is a biodiversity hotspot due in part to its unique location as a meeting point of land and sea with various types of aquatic climates. Wind, waves, tidal action and riverine flow have created unique coastlines, ranging from extensive tidal mudflats and saltmarshes to deeper tidal channels. More than 10 million birds either live within or 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 nutrient rich waters which allow large colonies of cockles and mussels to thrive, as well as the dune networks and mosaic of habitats providing resting and nesting grounds.

However, over the last decade, nearly half of the breeding bird species have continued to decrease in numbers. There are some indications that overfishing, as well as insufficient large roosting and moulting areas, could be behind these population dynamics.

A ruddy turnstone (*Arenaria interpres*) trolling the beachline at low tide in search of food. ©JV

A group of birds follows a fishing vessel back to land hoping to obtain an easy meal from any resulting discards. ©RHC



WorldView-1 image of a bird sanctuary delta, De Slufter, located on the first Wadden Isle of Texel (2009-04-03). This area is a key site for bird watching and nature walks which abuts on a restricted area specifically designated as a breeding ground for local and migratory bird species. DigitalGlobe (image created with ShowMySite): [WorldView 01 Texel] © [2009] DigitalGlobe, Inc. Data provided in the framework of the ESA Earthnet TPM Programme, through the ESA EOhopS project managed by CloudEO.

Ⓑ Modelling bird food sources through Earth observation

ECOPOTENTIAL is using 3D models to simulate the water quality of the region, providing indicators for mussels and cockles in the Wadden Sea. Satellites can detect the larger mussel and cockle colonies and the algae that support these molluscs. Sand and mud bars, which provide habitats for the colonies, can also be detected. By enhancing these images and including them in the model, better predictions of how these creatures will spread and develop across the Wadden Sea can be made, giving scientists valuable information on whether these food sources are growing or dwindling, and potential shifts in the trends. Policy and management strategies can also be incorporated into the model to determine how future food supply may be impacted by these strategies.

Sentinel-2 (2017-05-26) mosaic of several satellite observations (True colour) showing the extension of the Dutch Wadden Sea, up to and including the Ems Dollard, as outlined in the context of Natura2000 including a 20 km buffer around the edges. Produced from ESA remote sensing data (Sentinel-2). Image processed for ECOPOTENTIAL.

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This project is funded
by the European Union.

ECOPOTENTIAL

Improving future ecosystem benefits through Earth observations

ECOPOTENTIAL is a large European-funded H2020 project that focuses its activities on a targeted set of internationally recognised Protected Areas, blending Earth Observations from remote sensing and field measurements, data analysis and modelling of current and future ecosystem conditions and services. ECOPOTENTIAL considers cross-scale geosphere-biosphere interactions at regional to continental scales, addressing long-term and large-scale environmental and ecological challenges.

www.ecopotential-project.eu