

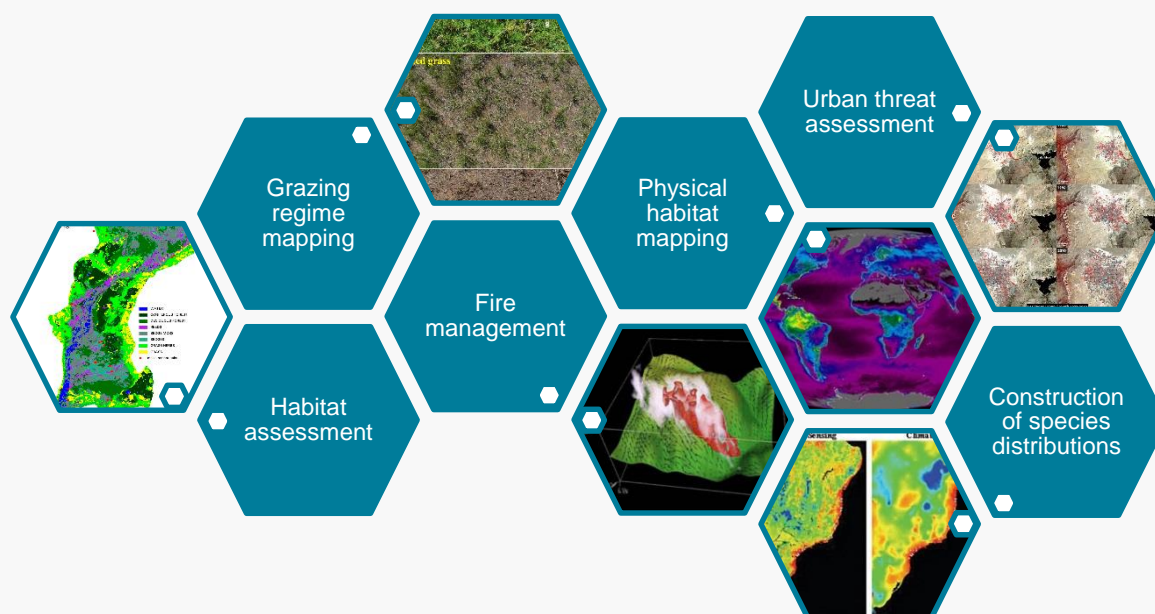
A view from above

Accessing and interpreting satellite remote sensing data for biodiversity management

Key messages

An increasing variety of satellite remote sensing data products which can be useful tools for biodiversity screening and management are becoming freely available. This briefing note provides an overview of open-access global remote sensing products derived for the terrestrial realm since 2000, and summarises current and emerging applications for biodiversity management.

- There are many freely available satellite remote sensing data products that can help with biodiversity screening and management. Higher resolution products are available at a cost.
- Satellite remote sensing data products can be used to assess and monitor change in land cover, give an indication of land use and can provide information on habitat quality and condition, especially if combined with other data and expert knowledge.
- Integration of remotely sensed information with species occurrence data can refine spatial datasets used for biodiversity screening.
- Making good use of remote sensing data products requires care and consistency of approach.
- Some specific biodiversity management-relevant applications of satellite remote sensing data products in combination with other data include:



Introduction

Satellite remote sensing has been used for decades in multi-purpose environmental monitoring and has evolved rapidly in response to societal needs. Satellite remote sensor technologies detect and classify observed objects on Earth.

There are a wide variety of remotely sensed information products which are freely available. Satellite remote sensing is becoming an increasingly important tool for biodiversity management, and conservation end users are increasing in

number. Satellite remote sensing allows users to:

- Acquire and store large amounts of surface imagery;
- Observe multi-annual time series data, consistently and systematically;
- Cost-effectively monitor extensive and/or remote and inaccessible areas.

Satellite remote sensing technologies are continuing to increase in scale, resolution and sophistication, and employing these can lead to significant

knowledge gains. While many of the datasets available through the Proteus Partnership or via the Integrated Biodiversity Assessment Tool are not currently updated or improved using satellite remote sensing, this technology is opening up new opportunities for the future.

This briefing note provides an inventory of remote sensing products for biodiversity management, addresses ambiguity between habitat, land cover and land use, and explores emerging applications and industry initiatives.

Box 1: Land cover, land use and habitat

Many biodiversity-relevant applications of remotely sensed data rely on measures of land cover, habitat and land use. These are related, but distinct concepts that require different combinations of information and have very different implications for biodiversity management. Understanding and correctly using these concepts is essential for effective application of remote sensing data.

From the perspective of biodiversity management, land cover, land use and habitat are area-based definitions of the terrestrial surface. But they differ in fundamental ways. **Land cover** is defined as the biophysical surface cover of the Earth which includes vegetation, water, crops, artificial surfaces and bare soil. **Land use** refers to the functional dimension of land for different human purposes or economic activities, such as forests for timber cultivation.

Land cover and land use are common terms, which are often (incorrectly), used interchangeably to describe the visible features of the Earth's land surface. It is important, however, to recognise the separation of the human dimension within land use as a concept. Neither land cover nor land use directly describe the area in which a species

lives, but they can indicate the condition of that area – i.e. the habitat suitability.

Land cover is typically and routinely classified from satellite images by recognition of patterns, shapes, spectral signature etc. (see Figure 1). Land use, however, with its human dimensions, is more challenging to map directly. With expert knowledge on the uses of classified land covers or by combining with other data, for example on legal designations, land cover can be transformed into land use classes.

Habitat is a more complex, species-specific term, describing where an organism is able to live. Habitat has both physical as well as biological meanings, and requires expert ecological knowledge to interpret on the ground. Three land cover/land use classification systems are frequently used to translate remotely sensed land cover classes into an appropriate habitat classification system:

- European CORINE Land Cover;
- FAO land cover classification system (LCCS);
- International Geosphere-Biosphere Programme Data and Information System's (IGBP-DIS) DIScover.

The satellite remote sensing community have largely adopted the LCCS framework (FAO, 2016). This is a hierarchical system which incorporates characteristics that are crucial determinants of habitat and can cope with the complexity of habitat definitions in terms of structural, biophysical and temporal components.

Land cover is a key indicator for biodiversity management due to its associations with habitat extent and condition. Land cover change can indicate human impacts on the terrestrial environment and signal threats to sensitive areas and species. Changes in land cover are often tracked as part of implementing the mitigation hierarchy and to inform policy. But there is often a need to explore these classes in more detail at a habitat level. Mapping habitats has many useful applications, but is much more time-consuming to assess and requires expert ecological knowledge.

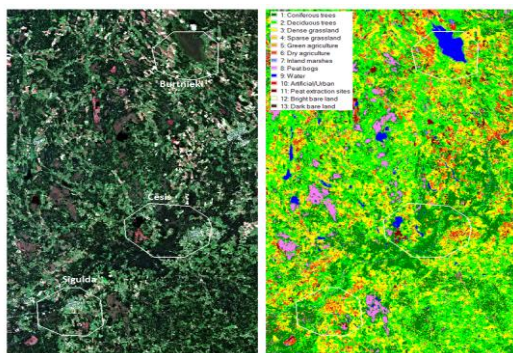


Figure 1. Land cover classification in Latvia from ESA's Sentinel-2 data. Visible colour image (left) and classification (right) (ESA, 2016).

Types of remote sensing

Satellite sensors can generally be grouped into those that are active or passive. Active systems generate their own sources of electromagnetic radiation, in contrast to passive systems which measure reflected solar radiation.

Active systems, for example synthetic aperture radar technology, can sense sub surface objects like soil, leaf tissue and shallow water. Typical applications include vegetation mapping in tropical zones, particularly mangroves and oil spill detection in the marine environment. Another active sensing technology, Light Detection And Ranging (LiDAR), is commonly flown on aircraft and used for precise digital terrain maps. There are plans for a space-borne LiDAR in the near future.

Passive sensors measuring reflected solar radiation are totally dependent on the illumination of the sun. The most commonly used passive systems are optical, multi-spectral scanners. These include NASA's Landsat and MODIS as well as the new Sentinel-2 satellite of the European Space Agency (ESA). Multi-spectral sensors have myriad applications but are most commonly used for land cover mapping, as well as in marine applications, such as monitoring phytoplankton blooms.

Tax payer funded, civilian space agencies provide low resolution imagery (>10m) and derivative products for free to the research community. In addition, a number of high spatial resolution (<4m) products are provided by commercial entities, such as Digital Globe. These satellites can be tasked for a fee, when and where imagery is needed. These are not included in the inventory accompanying this briefing.

Biodiversity applications for data products

The breadth and scope of data products from satellite remote sensing is vast. Biodiversity-relevant applications of specific data products range from assessing and managing threats to habitat monitoring and management in many different environments (Table 1). The annex to this briefing note (Annex A) presents an inventory and characterisation of 14 global, and freely available, satellite data products for the terrestrial environment from 2000 onwards.

Table 1. Possible biodiversity applications for a subset of the datasets listed in the inventory. For more information see Annex A.

Biodiversity application	Dataset (and provider)
Habitat assessment	Climate Change Initiative Land Cover (European Space Agency)
Aquatic habitat maps	Water bodies (European Commission Copernicus Global Land Service)
Fire management	Active fires (University of Maryland)
Physical habitat maps	Terrestrial vegetation parameters (European Commission Copernicus Global Land Service)
Urban threat assessment	Global urban footprint (German Aerospace Centre)
Constructing species distributions	Seasonality products (European Space Agency)

Emerging applications

Satellite remote sensing technology is quickly evolving and there are a number of emerging applications which may be available to support biodiversity management by 2030. Two particularly relevant examples include:

Near real-time deforestation detection and reaction systems

With the opening of the entire Landsat archive from 1972 for free, coupled with powerful cloud-computing platforms such as Google Earth Engine, analysts can now process millions of Landsat images simultaneously. This has enabled rapid advances in monitoring of deforestation from space.

The World Resources Institute's Global Forest Watch platform serves datasets such as the Landsat-derived global forest cover change dataset of Hansen et al. (2013), which covers the equivalent of 143 billion 30m Landsat pixels.

Annual estimates of forest loss and gain provide key insights into 21st century forest cover change. However, the creation of the Global Land Analysis and Discovery (GLAD) dataset, which comprises Landsat-derived 30m forest loss alerts in near real time, represents a 'game-changing technology' for reducing deforestation. GLAD is currently operational for a selection of tropical countries, and alerts users within days of a deforestation event. Therefore, presenting an opportunity to react to these events in near real-time (Hansen et al., 2016).

Terrestrial plant species mapping

The work of Asner et al. (2014) has demonstrated the possibility for tree-level, species discrimination by tracking unique genetic footprints in tree leaf foliar chemistry through hyperspectral remote sensing. The spectral signature of tree species can be tracked from hyperspectral sensors on-board aircraft, with tree species mapped across forests (see Figure 2).

A database of tree-level spectral signatures from airborne remote sensing methods is available for some pan-tropical countries and contains 13,000 specimens. It could be feasible to have a globally representative database of all tropical forest canopy vegetation by 2030. With NASA's planned launch of the first hyper spectral sensor on-board a satellite, the Hyperspectral Infrared Imager (HyspIRI). This database could be used to map tree species directly and globally from space.

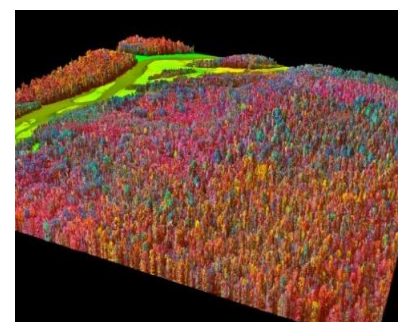


Figure 2. Chemical composition of a lowland Amazon forest. Similar colours indicate the presence of chemically-related species (Carnegie Airborne Observatory, 2016).

Box 2: Case-study - Refining mangrove species distribution data with satellite remote sensing

Refining biodiversity data with satellite imagery can be valuable in improving biodiversity management and decision making. Combining satellite imagery with biodiversity data provides a more powerful tool for management than either dataset could provide individually and it can help to screen for potential impacts on individual species in a meaningful way.

Expertly assessed mangrove species range maps from the IUCN Red List database are often used for management purposes due to the additional information associated with IUCN assessments, for example threat status and habitat preference. However these maps are coarse (see Figure 3) in comparison with the mangrove datasets derived from satellite imagery and held by UNEP-WCMC on the Ocean Data Viewer: Global Distribution of Mangroves (Giri *et al.* 2011 – USGS Landsat) and World Atlas of Mangroves (Spalding *et al.* 2010).

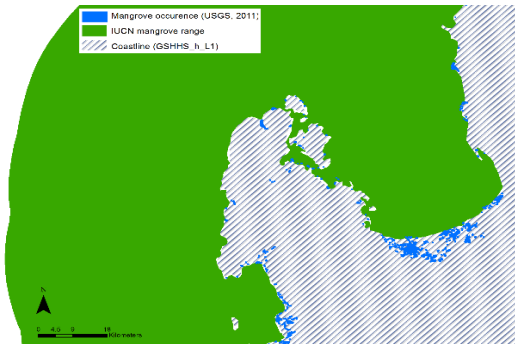


Figure 3. IUCN mangrove species range maps (IUCN, 2014; green) compared to the Global Distribution of Mangroves (Giri *et al.*, 2011; blue) in the Philippines.

In December 2014, UNEP-WCMC, in collaboration with IUCN, developed a methodology to refine species range maps with remote sensing data. Range maps for 68 endangered mangrove species were first corrected for geometry issues (see the Proteus Technical Briefing Note on data misalignments¹).

Using remotely sensed areas of known mangrove occurrence from USGS Landsat imagery, range maps were then refined for all threatened mangrove species. The output was a species-specific, remotely sensed layer of mangrove occurrence for each endangered species of mangrove. Figure 4 shows a section of the range of *Tabebuia palustris* in Panama.

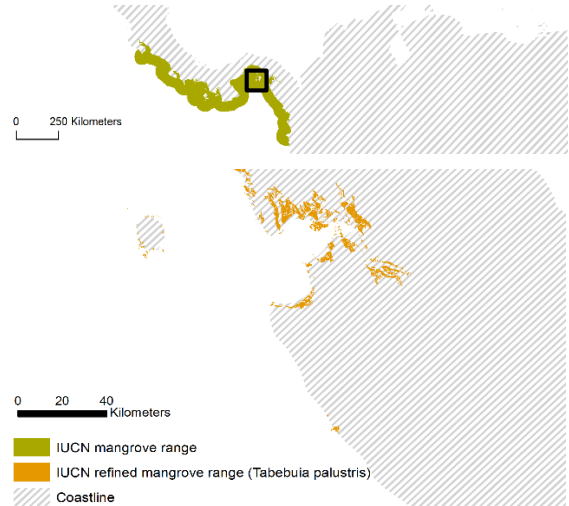


Figure 4. IUCN species range maps for *Tabebuia palustris* (orange) in Panama refined using USGS Landsat imagery. The original IUCN mangrove species range map is shown in green.

This methodology can be modified for any species range where known occurrence can be observed from satellite imagery. Other applications for refining spatial datasets include:

- Refining land use maps with spatial data on human activities to support minimising habitat loss caused by existing threats or operational impacts;
- Refining data on coastal habitats according to recent and predicted sea level rise in early screening stages for avoidance of priority species or habitats.

Industry initiatives

Private sector engagement with remote sensing agencies is widespread. The European Space Agency (ESA) has an Industry Portal² providing industry with opportunities to work with ESA on new projects, as well as informative material and educational tools. ESA is keen to expand its collaboration with industry through its programmes, including Earth Observation, and regularly announces collaborative opportunities.

The United States Geological Survey (USGS) has a technology transfer

program³ linking USGS scientists with the private sector, and collaborates with NGOs, governments and the private sector to further its science mission.

In addition, the European Association of Remote Sensing Companies (EARSC) is a professional industry body providing a network to exchange on best practice, and support future developments in remote sensing. EARSC have developed a portal for information exchange between the oil and gas industry and geo-information professional communities. The Oil and Gas Earth Observation group⁴ provides a comprehensive guide to products

meeting the needs of the industry⁵, such as land cover characterisation and forest fire mapping.

Concluding remarks

Satellite remote sensing data products can provide a reliable and repeatable source of information that can be used in combination with other data for specific biodiversity screening and management applications, for example assessing and monitoring land cover change. However, the use of remote sensing requires care and consistency, and often on-the-ground validation.

¹ www.proteuspartners.org/resources/out-of-line-out-of-mind-working-with-data-misalignments-in-global-biodiversity-spatial-datasets.pdf
² http://www.esa.int/About_Us/Business_with_ESA

³ <https://www2.usgs.gov/tech-transfer/>
⁴ <http://www.ogeo-portal.eu/>
⁵ <https://earsc-portal.eu/display/EO4/EO4OG+Home>

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A view from above

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Annex A

A comprehensive inventory of global, terrestrial, free and open-access satellite remote sensing products derived since 2000, which can be used for biodiversity management. There are six families of products: land cover (yellow), water bodies (blue), fire (orange), vegetation (green), urban (dark grey) and seasonality (light grey).

Dataset	Representative year(s)	Data provider	Satellite sensor	Spatial resolution	Attributes	Applications to biodiversity	Accessibility
Climate Change Initiative Land Cover	2000,2005,2010	European Space Agency (ESA)	Envisat MERIS	300m.	Uses the Land Cover Classification System	Change assessments of likely habitat	Online download and Terms of Use
GlobCover	2006,2009	European Space Agency (ESA)	Envisat MERIS	300m.		A static assessment of likely habitat	Online download and Terms of Use
Global Land Cover (GLC) 2000	2000	Joint Research Centre (European Commission)	SPOT-VGT	1km.			Online download and Terms of Use
Global Land Cover 30	2000 and 2010	National Geomatics Centre of China	HJ-1, Landsat	30m.	Ten land cover classes	Limited due to coarse class descriptions and poor accuracy in some classes	Online download and Terms of Use
Climate Change Initiative Water Bodies	2005-2010	European Space Agency (ESA)	Envisat ASAR	300m.	Presence/absence of permanent, inland water bodies	Assessment of recent water cover for aquatic habitat maps	Online download and Terms of Use
Global Water Surface Dynamic	1984 to 2015 (5-yearly updates)	Joint Research Centre (European Commission)	Landsat (moving to Sentinel 1/2)	30m.	Presence/absence, inter-annual, intra annual (monthly), inter annual, near real time	Assessment of vulnerability and resilience to disturbance	Online download and Terms of Use
Water Bodies	Jan 2014 - present	European Commission Copernicus Global Land Service	PROBA-V	1km	Water Body Occurrence (WBO)	Assessment of recent water cover for aquatic habitat maps	Online download and Terms of Use
Active fires	2001-present (every 8 days)	University of Maryland	Terra/Aqua MODIS	1km.	Presence/absence of fires burning at the time of satellite overpass	Active fire management for park rangers etc.	Online download and Terms of Use
Burnt Area	April 2014 – present (every 10-days)	European Commission Copernicus Global Land Service	PROBA-V	300m or 1km.	Burnt scars, i.e. surfaces where vegetation is damaged or destroyed by fires	Map grazing regime, assessing habitat degradation	Online download and Terms of Use
Biophysical vegetation variables	2000-present approx.	European Commission Copernicus Global Land Service	PROBA-V, SPOT-VGT	300m. or 1km	Biophysical variables describing the state, the dynamism and the disturbances of the terrestrial vegetation	Mapping habitat parameters, e.g. primary productivity	Online download and Terms of Use
Global Human Settlement Population Grid	1975, 1990, 2000 and 2015	European Commission Joint Research Centre	Landsat (but moving to Sentinel 1 and 2)	250m or 1km.	Distribution and density of population, expressed as the number of people.	Monitoring change in pressures on biodiversity from human populations	Online download and Terms of Use
Global Human Settlement Layer	1975, 1990, 2000, and 2014	European Commission Joint Research Centre	Landsat (but moving to Sentinel 1 and 2)	30m.	Percentage built-up area	Monitoring change in pressures on biodiversity from proximity to human settlement	Online download and Terms of Use
Global Urban Footprint	2011	German Aerospace centre (DLR)	TerraSAR-X TanDEM-X	75-84m.	Presence/absence of urban (man-made building structures with a vertical component)	A static assessment of urban threats to biodiversity	By request only (see link) and Terms of Use
Seasonality products	1998-2012	European Space Agency (ESA)	Envisat MERIS	300m.	Average dynamics and the inter-annual variability of Normalised Difference Vegetation Index, burnt area and snow (in 7-day time intervals)	Constructing climate envelopes for species distributions	Online download and Terms of Use