# Beyond Copernicus: New remote sensing approaches to habitat quality mapping and monitoring

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## 1. Introduction

Traditional methods of remote sensing for habitat quality mapping have most often focused on land cover mapping. While land cover is a very important characteristic of terrestrial habitats in the broadest sense, it rarely captures of the subtleties and complexities of habitats and by default generalises any notion of habitat quality. In remote sensing land cover classes are defined on the basis of human comprehension and conceptualisation of the land surface properties that can be distinguished in the spectral reflectance of the surface at different wavelengths from satellites or airborne sensors. This may make land cover an easily understandable interpretation of remote sensing data, but on the other hand, it is restricting the range of aspects of habitat quality that can be meaningfully characterised if all possible information retrievals from remote sensing were to be considered.

Biophysical parameters, in contrast to land cover classification, can provide important information related to habitat quality that is more directly related to the conditions found in nature. For example, knowledge of the gross primary productivity (GPP) of vegetation can be more significant in determining habitat quality than the type of land cover alone – imagine two types of improved grassland with high and low GPP or species diversity.

The Copernicus initiative, formerly GMES (Global Monitoring for Environment and Security), is Europe’s contribution to the Global Earth Observation System of Systems (GEOSS). It funds a series of initial operations of services in support of specific user needs and policies, as well as a series of five Sentinel satellite missions to provide long-term data continuity for operational monitoring.

The GIONET European Centre of Excellence in Earth Observation Research Training (www.gionet.eu) project has provided a supplementary research and development component to the Copernicus programme. It has explored and developed new and innovative monitoring services, some of which are relevant for habitat quality mapping and monitoring and are introduced here.

## 2. Remote sensing in support of habitat quality mapping and monitoring

### 2.1 Terrestrial habitats: Forest mapping and monitoring

Forest biomass is one of the world’s most important carbon pools and is at risk from tropical deforestation and land use change. The spatial distribution of forest biomass is also important as an indicator of habitat quality in forested or partially forested ecosystems. Forest biomass influences the light exposure and shading of the land surface, the magnitude of diurnal variations of land surface temperature and the soil moisture dynamics.

To date, most applications for forest mapping have used either optical or radar data, but rarely both. Synergies between radar, Light Detection and Ranging (LiDAR) and optical/infrared sensors can be used to improve the retrieval accuracy of aboveground forest biomass (Rodriguez-Veiga et al., in press).

A case study in Mexico by Rodriguez-Veiga et al. (in press) used MODIS 250 m reflectance bands and vegetation indices, the SRTM digital elevation model, and ALOS PALSAR L-band dual-polarization Synthetic Aperture Radar (SAR) imagery to map aboveground forest biomass at the national level at 250 m spatial resolution (*Figure 1*). L-band SAR backscatter generally increases with higher biomass up to around 150 t $ha^{-1}$ when the signal saturates. Above the saturation threshold, this method mostly relies on optical reflectance and the digital elevation model. The topographic elevation of the pixel is an important determinant of forest biomass, because the higher elevation areas are less subject to logging and forest degradation than the lowlands.

A maximum entropy approach was used to identify the relative variable importance and produce the final biomass map. ALOS PALSAR explains approximately 50.9% of variation in biomass, while MODIS showed 32.9% and SRTM 16.2% relative importance.

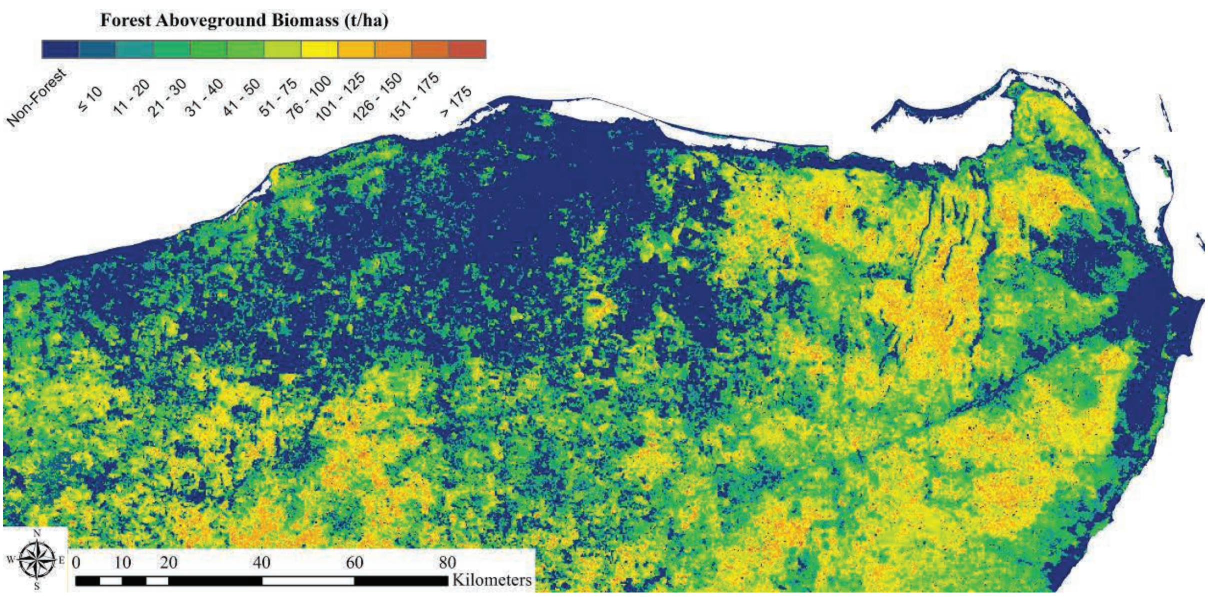



Figure 1: Map of Forest Aboveground Biomass at 250 m spatial resolution for the North coast of the Yucatán peninsula

In addition to forest aboveground biomass, more detailed investigations of biomass components can be made. In a study of high spatial-resolution airborne SAR data at S-band and L-band with co- and cross-polarised channels, Rodriguez-Veiga et al. (2013) found that, more detailed characteristics of the vertical biomass distribution in the canopy can be retrieved. *Figure 2* shows a map of tree crown biomass from Savernake forest, UK. This information was validated with forest inventory data collected in the field. Information on the spatial distribution of tree crown biomass can give important insight into the habitat quality for woodland birds and other tree-dwelling animals.

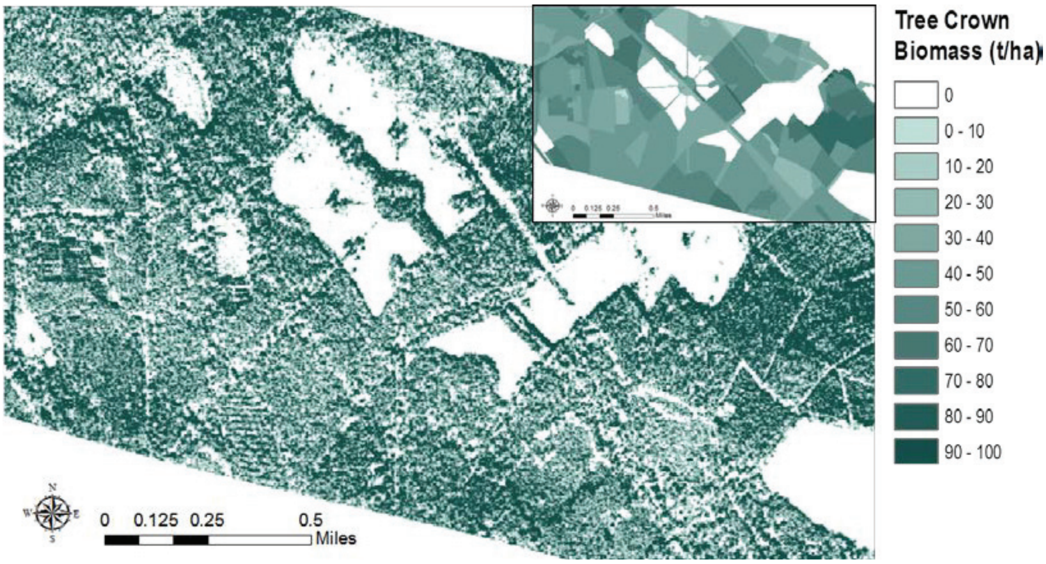



Figure 2: Map of tree crown biomass over Savernake forest, Wiltshire, UK, retrieved from S-band airborne SAR data acquired by Airbus Defence and Space. The inset shows the Forestry Commission stand boundaries.

### 2.2 Terrestrial/aquatic ecotones: Lakeshore monitoring

Hyperspectral images give sufficient detail to enable an analysis of the complex leaf level responses to environmental pressures. A case study by Stratoulias et al. (2014) for an ecotone on the shores of Lake Balaton in Hungary assessed the capability of hyperspectral imagers to detect the deterioration of reed (*Phragmites australis*), that is reed die-back. Die-back plants showed a marked change in spectral response, with a particularly useful signal being the red-edge position. *Figure 3*a shows a map of the lakeshore near the town of Tihany, classified from hyperspectral data, which highlights in red those reed areas that were detected as having a different leaf physiological response from other reed area (in shades of green).

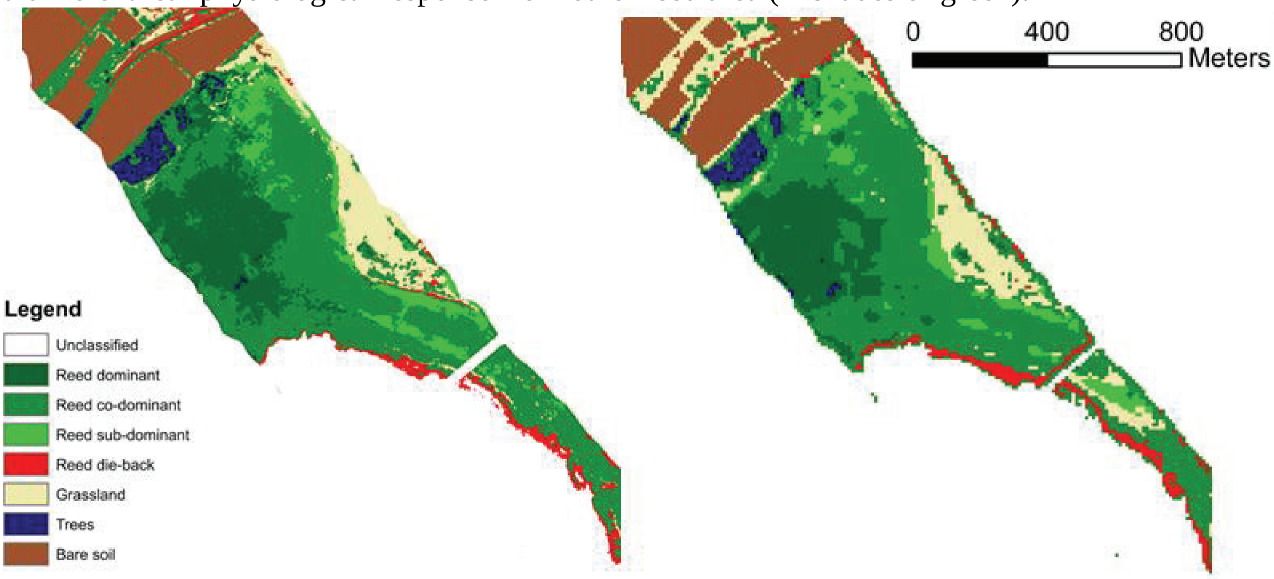



Figure 3: Maps of land cover classes and different reed dominance classes, as well as areas of reed die-back. Left: Map based on airborne hyperspectral data acquired during the EUFAR campaign at Lake Balaton, Hungary, 2010. From Stratoulias et al. (2013). Right: Simulated Sentinel-2 data product at reduced spectral and spatial resolution. From Stratoulias et al. (2014).

Such indicators of vegetation physiology and the condition of photosynthetic systems are powerful tools to assess vegetation health and consequently habitat quality.

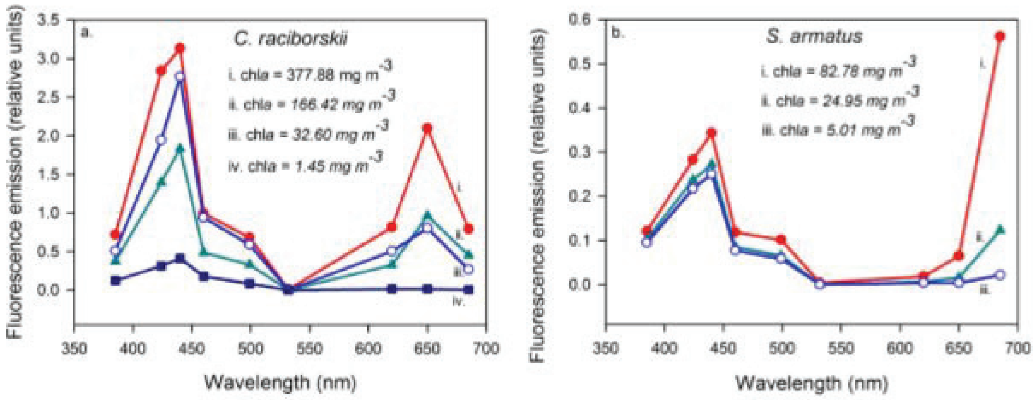
The forthcoming Sentinel-2 satellite mission will not have hyperspectral capability, but it has many spectral bands that differentiate well between the reed classes presented here. *Figure 3*b presents a simulated Sentinel-2 image classification derived from the airborne data, using only the bands also available from this satellite and after resampling to 10 m spatial resolution.

### 2.3 Freshwater habitats: Water quality monitoring

Palmer et al. (2013) describe the fluorescence signatures of two species of phytoplankton commonly found in the waters of Lake Balaton, in addition to robust retrievals of chlorophyll-*a* concentration, a common proxy for phytoplankton biomass generally, and water quality parameters through their laser induced fluorescence and backscattering signals. Species investigated are commonly found in Lake Balaton, Hungary, and include the potentially toxic cyanobacteria, *Cylindrospermis raciborskii*, which are especially important to monitor. An Ultraviolet Fluorescence LiDAR (UFL-9) was used in a lab experiment to complement *in situ* field measurements of the fluorescence response of the different parameters and species of phytoplankton at different wavelengths when illuminated with a UV laser pulse.

The potential of this new technique lies in the possibility to reliably map water quality parameters, which continue to pose a challenge via passive, satellite remote sensing despite great progress in recent decades. This application would provide information from ship-mounted UFL campaigns along the path of the ship and help understand the spatial and temporal dynamics of water quality, which plays a key role for habitat quality in aquatic and lakeshore ecotone environments. The abundant measurements, on a small to medium spatial scale, also render UFL measurements a potential source of calibration and validation data for satellite retrieval algorithm development.

At a coarser scale, the forthcoming Sentinel-2 mission provides new capabilities to derive spaceborne water quality maps at regular intervals.




(a) (b)

Figure 4: UFL fluorescence emission spectra (excitation laser pulse wavelength = 355 nm) for (a) *Cylindrospermopsis raciborskii* and (b) *Scenedesmus armatus* cultures of varying biomass concentrations. Measurements were obtained in controlled tank experiments. Reproduced from Palmer et al. (2013), *Remote Sensing*.

## 4. Discussion

The GIONET project has developed a range of innovative remote sensing techniques for mapping and monitoring habitat quality in different types of habitat. The Copernicus programme provides a continuous data stream from European Earth Observation satellites. It is accompanied by a series of operational services that target specific application areas and user needs. This paper argues that there is more potential to develop and implement innovative methods for using remote sensing to quantify biophysical parameters in support of habitat quality mapping and monitoring.

Three examples are provided: forest mapping, lakeshore ecotone mapping of reed beds and lake water quality assessment using UV fluorescence LiDAR. If these data products are continued as operational products or services, ecologists could study the impacts of climate variability, human pressures and environmental changes on the habitat quality. Deriving meaningful biophysical parameters from remote sensing is necessary for analysing ecohydrological processes such as evapotranspiration, soil moisture, photosynthetic activity and carbon storage at a finer spatial scale. The Sentinel satellites with their improved spatial and temporal resolutions will enable a much more relevant analysis of biophysical parameters at the scales that matter for habitat quality.

Ultimately, important ecosystem services such as the provision of food, timber, fuelwood, biodiversity, clean water etc. can be quantified by combining remotely sensed data with ecohydrological process models and economic valuation.

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