DIVERSITY II

Supporting the Convention on Biological Diversity

A project of the European Space Agency – Data User Element
Motivation

The Convention on Biological Diversity

And The Aichi Biodiversity Targets

Biological diversity (biodiversity) provides resources and ecosystem services upon which mankind is dependent. Since long, it is on the decline globally. The ongoing loss of biodiversity is a threat to human well-being, security and economic growth. Reversing these trends is a major environmental challenge facing the global community. The first global step to accept this challenge was the Convention on Biological Diversity (CBD). It was opened for signature at the UN Conference on Environment and Development in Rio de Janeiro in 1992 and entered into force in 1993. Since then, biodiversity conservation has developed into a key political issue and the CBD has become a major instrument for the conservation of biodiversity, both at national and international levels. At present, the Convention has 193 Parties, including the European Union.

The objectives of the CBD are “the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources”. The Convention translates these objectives into binding commitments in a number of substantive provisions.

In 2010 The 10th Conference of Parties contributing to the CBD adopted a Strategic Plan for Biodiversity for the 2011-2020 period. This Plan is now the overarching framework on biodiversity for the UN, other international organizations and national governments. The plan is constructed around 20 headline targets, also called the Aichi Biodiversity Targets.

One of the 5 strategic goals of the CBD is to “Enhance implementation through participatory planning, knowledge management and capacity building”. This is addressed by target 17: “By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of loss, are improved, widely shared and transferred, and applied.” The European Space Agency, through its Data User Element and together with key users from the CBD, has seen the potential role of Earth Observations (EO) to meet this Target, particularly in regards to status and trends of biodiversity. Two ecosystems, drylands and inland waters, were identified which are of critical importance as expressed in target 11: “By 2020, at least 17 per cent of terrestrial and inland water ... especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed ... protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.”
Project Objectives

In order to contribute to the assessment and monitoring of the Aichi 2020 Biodiversity Targets of the CBD, the Objectives of the Diversity II Project are to provide for selected key parameters, status maps, associated change maps, status indicators and trend indicators aggregated at different administrative and biome level. These key parameters are:

For Inland Waters

- Availability of freshwater through water extent and water level
- Quality of freshwater, reflected by its water constituents such as chlorophyll-a and/or suspended matter concentration, as well as by its temperature

The products will be provided on a global scale by producing results for 300 large perennial inland waters and covering a time range from 2002 to 2012.

For Drylands and sub-humid lands

- Net Primary Productivity (NPP), through the Vegetation Index (NDVI) and the fraction of absorbed photosynthetically available radiation (fAPAR) as indices on the vegetative/biomass productivity
- Rain use efficiency (RUE) as an index for the land/vegetation conditions (status and degradation)

The products will be provided on a global scale for more than 20 large dryland areas.

Earth Observation Technology

The primary data sources for the Diversity II Project are Earth Observation data from the ESA ENVISAT satellite, specifically from the MERIS, AATSR, RA-2 and ASAR instruments. Among these, the MERIS Full Resolution data will be the most important dataset. The project will also pave the way for a future sustainable provision of information using future satellites, such as the Sentinel-3 and Proba-V. The Diversity II Project has therefore the central technical objective to transform MERIS, OLCI and other coarse/medium resolution sensors observations into information required to support the CBD Strategic Plan. This comprises basic bio-geo-chemical parameters, such as chlorophyll concentration or fAPAR, and to define and develop a number of indicators for showing the status and trends of biological diversity in inland waters and in Drylands.
Project Plan

The Diversity II project started in September 2012 and will run for 2 years. The first 10 months are dedicated to a requirements consolidation, algorithm selection and development phase. The last 14 months are allocated to product generation and demonstration. The project is organised along the following key activities:

Link biodiversity users and EO experts

Professor Per Wramner leads the Diversity User Bureau (DUB). The DUB coordinates the Diversity User Group, a cross cutting activity which runs in parallel to the technical tasks and focusses on all user interactions in one place. Based on his long term involvement in the CBD process and – on the other hand – his technical expertise, Per facilitates the dialogue between the biodiversity users and the EO experts of the team, making sure that the most suitable indicators will be generated, and keeping the users closely attached to the project.

Selection of best algorithms

Deriving the basic water quantity and water quality parameters for inland waters is a challenge. In particular there are still methodological problems, specifically for the atmospheric correction, that need to be solved to derive parameters for optically complex waters. A comparison of various algorithms, including several atmospheric correction approaches such as the MERIS Lakes, Case2R and FUB algorithms for inland waters, and using in-situ data and simulated data as reference for validation.

EO based approaches to the assessment of dryland conditions and assumptions with regard to biodiversity are primarily dependent of the geographic scale and related ground information. Global and continental assessment analyse time series data of above ground green biomass, which are estimated for fixed increments of time (most typically decades, months, years) using EO derived vegetation indices or bio-physical indices. Most commonly, NDVI, the Normalised Difference Vegetation Index, is used as a proxy for NPP. We will refer to NDVI based heritage methods to maintain monitoring continuity, but we will also use more advanced indices, such as fAPAR, and model approaches for future assessments and to support policy development and implementation. Subsequently, efficiency indices will relate NPP indices to their driving forces.
Software and production

The software to generate the Diversity II Products is complex and has to work on very large amounts of data efficiently. The processing chain includes steps from child product generation, merging of data from different sensors and sources, cloud screening, atmospheric correction, bio-optical inversions, indices calculation, spatial and temporal integration, change detection, indicator calculation, up to the final map generation. The production involves processing of more than 100 terabytes of input data. The new algorithms will be developed largely using the ESA BEAM toolbox, and will also be based on existing processing modules (ERDAS).

The production plan includes:

- March 2013: prototype products for 4 lakes and 3 drylands, generated with different algorithms for algorithm intercomparison
- June 2013: prototype products for 10 lakes and 5 drylands, generated with the finally selected proposed algorithms
- October 2013: qualified products for 10 lakes and 5 drylands, generated with the final algorithms, for qualification of the production system
- April 2014: all products (300 lakes and more than 20 drylands) for assessment by users
Validation

Validation is a key to acceptance of the products by the users, and this is the vital to the success of the project. The basic EO parameters, i.e. for land the surface reflectances and the vegetation indices, and for water the water leaving reflectance, IOPs, chlorophyll-a concentration, Total Suspended Matter (TSM) concentration, turbidity/Secchi Depth, will be validated using in-situ data and based on international standard protocols, such as the MAVT protocol. A detailed validation of the indicators will be performed by using multi-scale species database.

Communication and product dissemination

The WebPortal (www.diversity2.info) provides background information about biodiversity in Inland Waters and Drylands, and about the project. All project deliverables are published here. The Diversity products will be made available through a WebGIS interface. They are complemented by a user handbook, which includes a tutorial for working with the Diversity products, and presenting Biodiversity stories to provide detailed material about the biology of the sites and the value brought by the EO products.

Preparing the future

To reach the objective of the Diversity II Project, i.e. to support the implementation of the 2011-2020 biodiversity Strategic plan, a vision is required and planning that do not end after 24 months, when the project is completed. Lessons learnt during the project will be assessed, limitation of the approach will be identified and recommendation for improvements will be given. A technical analysis will be undertaken in order to analyse the possibilities, constraints and possible improvements of a continuation and further development of the Diversity II Products in the era of the Sentinels and Proba-V.
Diversity II Products

Inland Water products

Water Quality

**Water Constituents**
Data source: MERIS Full Resolution
Parameters: Turbidity, Secchi Disk depth, chlorophyll-a concentration, suspended sediment concentration, yellow substance absorption; quality indicator; variance of parameter during averaging interval
Spatial resolution: 300m
Temporal averaging: daily / monthly / yearly

**Lake Surface Water Temperature**
Data source: AATSR (ARC Lake dataset)
Parameters: Lake Surface Water Temperature (LSWT), Uncertainty estimate for lake surface temperature, Chi-squared (goodness of fit measure for OE retrieval); Variance of LSWT over averaging period/area over averaging period/area
Spatial resolution: 0.05 degree grid / Lake-mean
Temporal averaging: None / Climatology / Timeseries

Water Quantity

**Water Level**
Data source: Radar Altimeter (River and Lakes database)
Parameters: Water height difference to reference level, water volume difference
Spatial resolution: one or more points per lake (crossing points of altimeter tracks)
Temporal averaging: time series

**Water Extent**
Data source: ASAR WS (LC-CCI processing) + MERIS Full Resolution
Parameters: land-water mask
Spatial resolution: 300m
Temporal averaging: 1 map derived from 10 year time series; for some areas a seasonal climatology is available; temporal variability from combination with optical data
First level indicators: status maps and trends

First level indicators are derived from the basic parameters above by spatial and temporal aggregation in order to indicate trends.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indicator for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chla</td>
<td>Eutrophication</td>
</tr>
<tr>
<td>TSM</td>
<td>Physical disturbance</td>
</tr>
<tr>
<td>Yellow Substance</td>
<td>Contamination</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Physical disturbance and/or contamination</td>
</tr>
<tr>
<td>Secchi Depth</td>
<td>Physical disturbance and/or contamination</td>
</tr>
<tr>
<td>Temperature</td>
<td>Eutrophication</td>
</tr>
<tr>
<td>Volume and extend</td>
<td>Physical disturbance, rain fall</td>
</tr>
</tbody>
</table>

Summary Table of First Level Inland Water Indicators

<table>
<thead>
<tr>
<th>Map/Indicator</th>
<th>Derived from</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean &lt;Parameter&gt; Epoch 1</td>
<td>Mean from period 2004 - 2006</td>
<td>Low, moderate, high parameter concentrations/transparency</td>
</tr>
<tr>
<td>Mean &lt;Parameter&gt; Epoch 2</td>
<td>Mean from period 2007 - 2009</td>
<td>Low, moderate, high parameter concentrations/transparency</td>
</tr>
<tr>
<td>Mean &lt;Parameter&gt; Epoch 3</td>
<td>Mean from period 2010 - 2012</td>
<td>Low, moderate, high parameter concentrations/transparency</td>
</tr>
<tr>
<td>Lake Status</td>
<td>Classification</td>
<td>Poor, moderate, high status</td>
</tr>
<tr>
<td>Trend &lt;Parameter&gt; Epoch 1/2</td>
<td>Mean (2004-2006)/Mean (2007-2009)</td>
<td>0-0.8 = negative diversity trend (NegDiv) 0.8-1.2 = No change (NoChange) 1.2+ = positive diversity trend (PosDiv)</td>
</tr>
<tr>
<td>Trend &lt;Parameter&gt; Epoch 2/3</td>
<td>Mean (2007-2009)/Mean (2010-2012)</td>
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<tr>
<td>Lake Trend</td>
<td>T1 and T2</td>
<td>POS, NEG, STABLE, UNCERTAIN</td>
</tr>
</tbody>
</table>

Second level indicators: habitat maps and link to biodiversity

Second level indicators combine several of the above water quality and water quantity parameters, complement them with additional information such as land use, and derive a value added product that relates to biodiversity data.

One second level indicators will be the determination of area of the pelagic photic zone and the area of the aphotic zone of each lake which is generated by combination of water transparency, water level and bathymetry. The changes in water level provide further information about the condition of the photic zone.
Dryland products

Status of Vegetation Productivity and Water Use Efficiency

Maps of vegetation productivity
- Full vegetation years (wet + dry season)
- Vegetation seasons
- “Epochs” (3 vegetation years)

Maps of rain/soil moisture/water use efficiency
Based on spectral indices for Net Primary Production (NPP) and rainfall/soil moisture/evapotranspiration data.

Data sources:
MERIS Full Resolution 300m, TRMM/GPCP rainfall, CCI Soil Moisture, MODIS evapotranspiration

NPP Indices:
- MERIS fAPAR - fraction of photosynthetically active radiation absorbed by the vegetation
  Parameters: fAPAR, NPP, rectified reflectance bands of the NIR and RED
- MERIS NDVI
  Parameters: NDVI, derived from RED and NIR rectified reflectance; AVHRR compatible NDVI

Temporal integration of NPP indices: half months

Changes and Trends of Vegetation Productivity and Water Use Efficiency

Change maps of vegetation productivity
- Full vegetation years (wet + dry season)
- Vegetation seasons
between “epochs” (3-year periods 2002 – 2012)

Change maps of rain/soil moisture/water use efficiency
between “epochs” (3-year periods 2002 – 2012)

Trend maps
- Vegetation productivity (MERIS fAPAR, NDVI)
- Rain use efficiency
- Soil moisture use efficiency
- Water use efficiency
- Rainfall
- Soil moisture
- Evapotranspiration
based on vegetation years and seasons 2002 to 2012
Changes and Trends of Vegetation Productivity and Water Use Efficiency

Spatial Aggregation of status, change and trend maps

- Protected areas
- Land cover types and classes
- Aridity
- Administrative regions

Second level indicators

Second level indicators combine several of the above listed contents and complement them with additional information such as land use or biodiversity data, thus aiming at establishing links to biodiversity and its drivers. Compared to the descriptive level of the status, change and trend maps of vegetation productivity, the second level indicator maps will provide more abstract information on the dynamics of vegetation productivity, drivers, and potential biodiversity trends. The indicators will be defined in detail during the first project phase.

Summary Table of Dryland Products

<table>
<thead>
<tr>
<th>Status of Vegetation Productivity and Water Use Efficiency</th>
<th>Changes and Trends of Vegetation Productivity and Water Use Efficiency</th>
<th>Second Level Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPP indices: MERIS fAPAR for</td>
<td>Changes and trends of NPP indices:</td>
<td>Classified size and direction of changes and trends of NPP indices (MERIS fAPAR) combined with status information</td>
</tr>
<tr>
<td>- vegetation years,</td>
<td>- MERIS fAPAR</td>
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<tr>
<td>- vegetation seasons and epochs (3 vegetation years)</td>
<td>- Changes between epochs</td>
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<td></td>
<td>- Trends of vegetation years and seasons</td>
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<tr>
<td>NPP indices: MERIS NDVI for</td>
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<tr>
<td>Rain Use Efficiency based on NPP indices and rainfall data for</td>
<td>Changes and trends of Rain Use Efficiency:</td>
<td>Classified size and direction of changes and trends of Rain Use Efficiency combined with selected parameters and indices</td>
</tr>
<tr>
<td>- vegetation seasons</td>
<td>- MERIS fAPAR</td>
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<td>- and epochs</td>
<td>- Changes between epochs</td>
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<td></td>
<td>- Trends of vegetation seasons</td>
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<tr>
<td>Soil Moisture Use Efficiency based on NPP indices and soil moisture data for</td>
<td>Changes and trends of Soil Moisture Use Efficiency:</td>
<td>Classified size and direction of changes and trends of Soil Moisture Use Efficiency combined with selected parameters and indices</td>
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<td>Water Use Efficiency based on NPP indices and evapotranspiration data for</td>
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</table>

Product aggregation at various levels, e.g.: Protected areas, Land cover types and classes, Aridity, Administrative regions and Continents.
Geographical Coverage

The Diversity II products will be generated for a global set of areas. A preliminary selection has been made which will be finalised by April 2013:

- **300 large perennial inland waters.** The Map shows a selection of 10 lakes which are chosen for in-depth validation of the methods.

- **More than 20 large dryland areas;** the map shows the current provisional location of the areas.

Initially selected dryland sites
Team

**European Space Agency**
Project requirement definition; user interface; EO data provision; project control

**Brockmann Consult GmbH, Germany**
Prime contractor; project management; algorithms for preprocessing including atmospheric correction over land and lakes; software and production

**GeoVille, Austria**
Drylands requirements analysis; algorithms for drylands; software and production

**Brockmann Geomatics AB, Sweden**
Biodiversity and user interface; algorithms for in-water retrieval and lake indicators; website, web GIS, communication and outreach

**Research Centre in Biodiversity and Genetic Resources CIBIO, Portugal**
Requirements engineering, validation

**Group of Consultants**
Dr. Sampsa Koponen (Finnish Environmental Institute SYKE) - remote sensing of inland waters in boreal areas; Dr. Kai Sorensen (NIVA) - Norwegian and African Lakes expert. Dr. Steven Greb (chair of the GEO Inland and Near Coastal Water Working Group) - lake remote sensing in North and South America. Prof. Rasmus Fensholt (Uni Copenhagen) - Earth Observation ecology studies of terrestrial dryland ecosystems. Dr. Kurt Günther (DLR) - Soil-Vegetation-Atmosphere-Transfer (SVAT) modelling and validation