Developments toward a European Land Monitoring Framework

Geoff Smith
Specto Natura Limited

- Enable clients to deliver useful, accurate and reliable environmental information from EO.
- Positioned at the interface between technology development, service provision and user requirements.
- Experience in national and European R&D and operational programmes.
Formerly known as Global Monitoring for Environment and Security (GMES)

… the European Programme for the establishment of a European capacity for Earth Observation.
A complex landscape analysis
Complex landscape analyses
Multi-step model ...

Semi-automated analysis and integration

Earth Observation and ancillary data

Land cover / land use mapping and biophysical properties

Local knowledge on habitat definitions and pressures

Habitat identification (extent and condition)

Expert understanding of ecosystems and biodiversity associations

Biodiversity assessment and ecosystem services

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Multi-step model ...

Data

Information

Integration

Earth Observation and ancillary data

Land cover / land use mapping and biophysical properties

Habitat identification (extent and condition)

Biodiversity assessment and ecosystem services
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Copernicus

- **Sentinels:**
  - S1 – C-band SAR
  - S2 – Super spectral HR optical
  - S3 – Super spectral MR optical

- **Services:**
  - Local
  - Continental / pan-European
  - Global
The Sentinel family

Sentinel 1 (C-band SAR, HR)

Sentinel 2 (Super-spectral optical, HR)

Sentinel 3
(Super-spectral, optical, MR)

Sentinel 4 / 5 / 6
(Meteorological / climate missions, links to MeteoSat, MetOp, optical, LR)

Images courtesy of ESA

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Sentinel-1

- Continuity of ERS-1, ERS-2, Envisat and Radarsat
- Synthetic Aperture Radar (SAR) mission.
- All-weather day-and-night operation.
- Two main modes: Interferometric Wide Swath and Wave.
- Swath width of 250 km
- Spatial resolution of 5×20 m.
- Revisit time of 1-3 days across Europe, Canada and shipping lanes.
- First Sentinel-1 launched in April 2014.
S-1 examples
S-1 examples
Sentinel-2

- Continuity of SPOT, IRS LISS and Landsat like data.
- Optical payload with visible, near infrared and shortwave infrared sensors.
- 13 spectral bands.
  - 4 bands at 10 m, 6 at 20 m and 3 at 60 m.
- Swath width of 290 km.
- With two satellites, revisit time of 5 days at the equator and 2–3 days at mid-latitudes.
- Always on over land
- The first satellite launched on 23 June.
S-2 spatial and spectral

Sentinel 2 simulations (Courtesy ESA)

Sentinel 2 bands (courtesy ESA)
S-2 examples

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S-2 examples
Sentinel-3

- Continuity of ERS-2 and Envisat.
- Sea and Land Surface Temperature Radiometer (SLSTR)
  - Visible, infrared, thermal infrared.
  - Spatial resolution of 500 m and 1 km
- Ocean and Land Colour Instrument (OLCI)
  - 21 bands, spatial resolution of 300 m
- Synthetic Aperture Radar Altimeter (SRAL)
  - Spatial resolution of ~300 m
- Revisit of less than a day to two days.
- Launch in late 2015.
Continental: High Resolution Layers / CLC

- **Imperviousness**
  - Sealing density

- **Forest**
  - Crown cover density
  - Forest types

- **Grassland**
  - Grass surface indicator

- **Wetland**
  - Wetland indicator

- **Corine Land Cover**
  - Land cover / use mapping

- **Water**
  - Permanent and transient areas

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Land Services: Pan-European Component

• CORINE Land Cover (CLC)
  – Land cover land use mapping
  – 25 ha (5 ha) MMU
  – 6 year update cycle
  – Member State produced

• Limitations
  – MMU too coarse
  – Changes happen quickly
  – Changes are smaller
  – Biophysical info needed
Land Services: HRLs

- Specifications:
  - Raster format.
  - Intermediate products 20 m spatial resolution.
  - Final products at 100 m spatial resolution.
  - Continuous variables and masks.
  - 3 year update cycle.
- Layers:
  - Imperviousness.
  - Forest (tree cover density & type).
  - Permanent grassland.
  - Wetland.
  - Permanent water bodies.
Imperviousness (IMD)
Forest tree cover density (TCD) & type (FTY)
Permanent Grasslands (GRA)
Wetlands (WET)
Permanent Water Bodies (PWB)
HRLs summary....

- Full pan-European validation is underway.
- Grassland and wetland layers being re-defined.
- Organisation of production is also likely to change.

- A new way of thinking about EO-based land surface products at sub-global level.
- Not an end product in themselves.
- Consider them as support layers.
- European focus, but applicable at MS and below.
- A lot has been learnt from the GIO exercise.
- Future iterations will include Sentinel data.
Local: Urban Atlas (Edinburgh)

- Continuous Urban Fabric (S.L. > 80%)
- Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
- Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
- Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)
- Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
- Isolated Structures
- Industrial, commercial, public, military and private units
- Fast transit roads and associated land
- Other roads and associated land
- Railways and associated land
- Airports
- Mineral extraction and dump sites
- Construction sites
- Land without current use
- Green urban areas
- Sports and leisure facilities
- Agricultural + Semi-natural areas + Wetlands
- Forests
- Water bodies
Local: Urban Atlas

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Local: Urban Atlas - Change

2006  2012
## Global Land Services

### Portfolio

#### Bio-geophysical variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Temporal Coverage</th>
<th>Temporal resolution</th>
<th>Spatial coverage</th>
<th>Spatial resolution</th>
<th>Sensor</th>
<th>Timeliness</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAI/FAPAR/FCover</td>
<td>1999 – present</td>
<td>10 days</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
<tr>
<td>NDVI/VCI/VPI</td>
<td>1999 – present</td>
<td>10 days</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
<tr>
<td>Dry Matter Productivity</td>
<td>2009 – present</td>
<td>10 days</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
<tr>
<td>Burnt Area</td>
<td>1998 – present</td>
<td>1 day</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
<tr>
<td>TOC Reflectance</td>
<td>2013 – present</td>
<td>10 days</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
<tr>
<td>Surface Albedo</td>
<td>1999 – present</td>
<td>10 days</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
<tr>
<td>Land Surface Temperature</td>
<td>2009 – present</td>
<td>1 hour</td>
<td>Global</td>
<td>0.05°</td>
<td>Σ Geo</td>
<td>1 day</td>
</tr>
<tr>
<td>Soil Water Index</td>
<td>2007 – present</td>
<td>1 day</td>
<td>Global</td>
<td>0.1°</td>
<td>Metop / ASCAT</td>
<td>1 day</td>
</tr>
<tr>
<td>Water bodies</td>
<td>1999 – present</td>
<td>10 days</td>
<td>Global</td>
<td>1km</td>
<td>SPOT/VGT</td>
<td>3 days</td>
</tr>
</tbody>
</table>
Global: Leaf Area Index (LAI)
The EAGLE concept

- EAGLE = EIONET Action Group on Land monitoring in Europe

- LC/LU experts from:
  - National land monitoring initiatives
  - National Reference Centers (NRC) Land Cover
  - INSPIRE Technical Working Groups (TWG)
  - ETC SIA (now ULS) partners
  - FP7 HELM consortium
  - Consultations with CLC Technical Team

- Founded through self-initiative of experts from various European countries (DE, HU, RO, CZ, NL, UK, CH, NO, FI, PT, AT, ES, CT)

- Open and voluntary participation
One more hurdle… Which nomenclature?
Main land issues ...

- Fragmented user community at many levels.
- Multitude of applications working with land information.
- Many classification systems and nomenclatures.
- Mixture of land cover and land use information.
- Growing need for better integration and harmonization of land monitoring initiatives.
- Bottom-up integration (regional to national) approaches.
- Relevance for all land monitoring activities.
Starting point... characterise or classify?

Classifications
- Grassland ≠ pasture ≠ lawn ≠ natural grassland

Characterization
- Growth structure
  - homogenous
  - heterogenous
- Growth density
  - closed
  - sparse
- Moisture
  - wet soil
  - surface water
- Use
  - intensive
  - extensive
  - sports
- Management
  - multiple mowing
  - single mowing
- Ecosystem type
  - inland marsh
The EAGLE approach

Rather than develop a fix nomenclature, information on landscape is compiled and described within three separate main general categories …

A.) LAND COVER Components – LCC
   Abiotic, Vegetation, Water Surfaces

B.) LAND USE Attributes – LUA
   Agriculture, Forestry, Industry, Transportation etc.

C.) further CHARACTERISTICS – CH
   Spatial pattern, bio-physical parameters, ecosystem types, land management practices, etc.
Uses: Describing landscape: Village (Built-up)

Land cover components (LCC):
• Conventional buildings,
• Broadleaved trees,
• Herbaceous plants,
• Open sealed surfaces

Land use attributes (LUA):
• Permanent residential,
• Agriculture / production for own consumption,
• Road network

Further characteristics (CH):
• Soil sealing degree = 35%
• Built-up pattern = discontinuous, single houses
## Uses: Decomposing class definitions

Examples of two CORINE class definitions

<table>
<thead>
<tr>
<th>LEVEL 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1.1 Continuous urban fabric:</strong></td>
</tr>
<tr>
<td>Most of the land is covered by structures and transport network.</td>
</tr>
<tr>
<td>Buildings, roads and artificially surface areas cover more than 80% of</td>
</tr>
<tr>
<td>the total surface. Non-linear areas of vegetation and bare soil are</td>
</tr>
<tr>
<td>exceptional.</td>
</tr>
</tbody>
</table>

| **1.1.2 Discontinuous urban fabric**                                    |
| Most of the land is covered by structures. Buildings, roads and        |
| artificially surface areas are associated with vegetated areas and     |
| bare soil, which occupy discontinuous but significant surfaces.        |
| Between 10% and 80% of the land is covered by residential structures.   |
### Uses: Semantic comparison tool

#### ABiotic / Non-vegetated

<table>
<thead>
<tr>
<th>Natural Material Surface</th>
<th>Woody Vegetation</th>
<th>Herbaceous</th>
<th>Shrub R</th>
<th>Urban Vegetation</th>
<th>Urban Water</th>
<th>Rural Water</th>
<th>Water Bodies</th>
<th>Water Storage</th>
<th>Snow</th>
<th>Ice/Glacier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Sealed</td>
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<td></td>
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<tr>
<td>Consolidated</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un-Consolidated Surface</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

#### Biotic / Vegetation

<table>
<thead>
<tr>
<th>Trees</th>
<th>Bushes/Shrubs</th>
<th>Graminaceous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Water

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Footnotes:**

1. The absence of a numerical value indicates the element was not present.
2. The elements are grouped in the order of importance and abundance.
3. The presence of multiple elements can indicate complex interactions or processes.

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**Legend:**

- **CLC:** Discontinuous urban fabric
- **Urban Atlas:** Discontinuous urban fabric (S.L. 10 - 80%)
- **SIOS:** Discontinuous
- **HRLs:** Imperviousness
- **LGN NL:** Semi urban built-up areas
- **CH Arealstatistic:** One- and two-family houses

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Take home messages....

- Copernicus Sentinel data
  - Step change in observing capacity.
  - Sentinel 1A SAR data has been operational for over a year.
  - Sentinel 2A optical data is about to become operational.
  - Sentinel 3A ready for launch, B units phased in over next years.
  - All data available via free and open access at the Sentinels Scientific Data Hub.
  - UK Collaborate Ground Segment and STFC-CEDA
Take home messages….

• Copernicus Land Services: HRLs
  – European focus, but applicable at MS level and below.
  – Consider them as support layers.
  – Quality is variable between layers and to a lesser extent spatially.
  – Opportunities to refine and enhance layers if sufficient user feedback.
  – 2012 HRLs will be launched now….?
  – 2015 tendering process starting on Friday
Take home messages....

• EAGLE concept
  – Data model available that can be used as a basis for land monitoring.
  – On-line comparison tool used to study and compare nomenclatures.
  – Geometric testing supporting CLC2018.
  – Integration within Copernicus, revised HRL specs.
  – A number of projects adopting / adapting the approach
  – The continuation of the exploitation and evolution essential to the harmonisation of land monitoring in Europe.
Conclusions

• These are exciting times in the use of space for solving issues at field to continental scales in general.
• Complex landscape analyses such as biodiversity mapping require multi-scale / multi-faceted inputs.
• The Copernicus programme is now beginning to deliver the required data, information and support.
• The Sentinels (1, 2 & 3) are offering the required land surface measurements.
• The Copernicus Land Service is providing a number of suitable support products.
• There is now a major opportunity for end users and downstream service developers to implement innovative solutions which exploit these information sources to address important issues and provide economic growth.
Any other questions?

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