



Earth Observation LULC Products in support of Ecosystem Monitoring in the EU



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Environment, Geoscience and Remote Sensing

European Association of Remote Sensing Laboratories
Special Interest Group in Land Use & Land Cover
Chairman

Upcoming event:

“Advancing horizons for land cover services entering the big data era”



6th EARSeL SIG LU/LC & 2nd EARSeL LULC/NASA LCLUC Workshop

Charles University in Prague
Prague, Czech Republic, 6-7 May, 2016





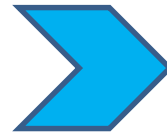
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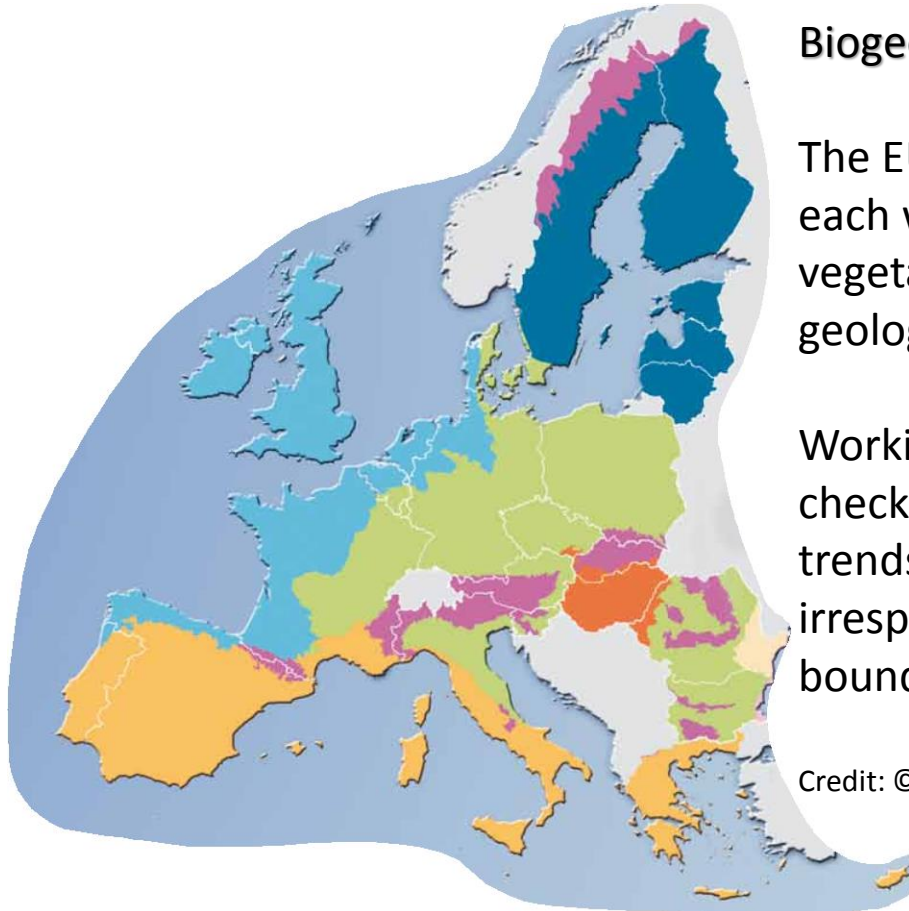


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Framework conditions





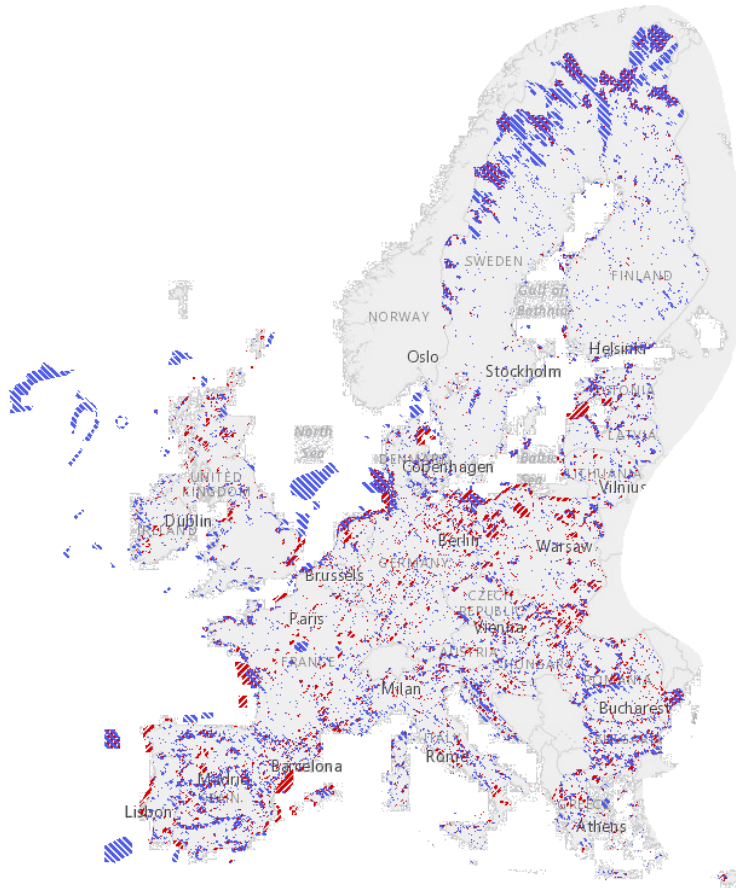
Biogeographical regions:

The EU has nine biogeographic regions, each with its own characteristic blend of vegetation, climate topography and geology.

Working at this level makes it easier to check species and habitat conservation trends under similar natural conditions, irrespective of political and administrative boundaries

Credit: © European Communities, 2009





- Member States identify sites that are important for the conservation of species and habitats listed in the Habitats Directive occurring naturally in their territory based on purely ecological grounds.
- European Commission examines the information provided across the whole biogeographical region and, in cooperation with all relevant actors, selects sites of Community importance.
- Member States formally protect these areas and introduce measures to maintain or restore them to a good conservation state.

Credit: © European Communities, 2009

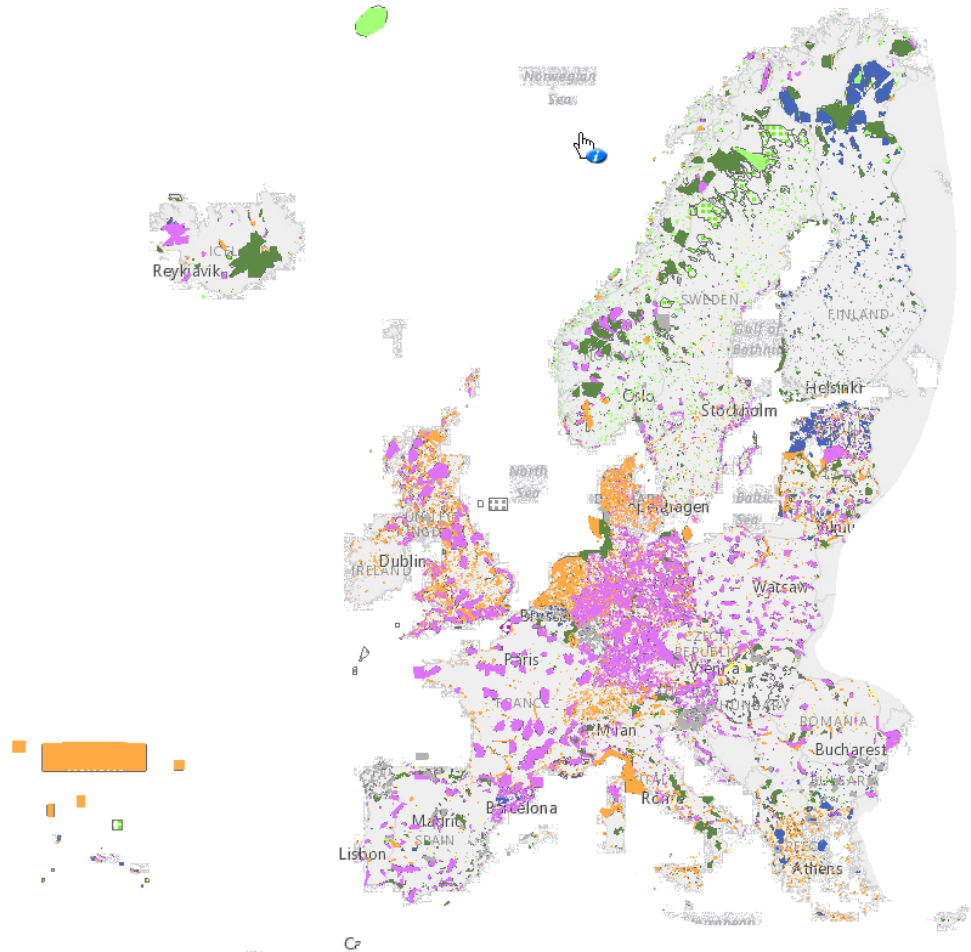
Blue lines: Habitats Directive Sites (pSCI, SCI or SAC)

Red lines: Birds Directive Sites (SPA)

Scale under 1:10.000.000

Credit: European Environmental Agency (EEA)





CDDA – IUCN categories:

- Strict Nature Reserve (I)
- National Park (II)
- Natural Monuments (III)
- Habitat/ Species Managements Area (IV)
- Other
- Protected Landscape/ Seasca[e(V)
- Managed Resource Protected Areas (VI)

Credit: European Environmental Agency (EEA)



Strengths & Weaknesses

Strengths	&	Weaknesses
Regional, transnational approach		Not all Member States took it as seriously as they should have
Based on biogeographic regions		More rational approach to selection of regions
Common classification of species and habitats		Unsystematic in subdivision of habitats
Site and area focus		Lacks focus on connectivity
Encouragement to restore habitats		Selection of priority habitats unsystematic
Encouragement to re-introduce lost species		Little activity in most Member States
Expert scientific basis		Difficult for non-expert to engage
Top down approach ensures action		Top down approach causes conflict with key stakeholders
NGOs played positive role in implementation		Opponents feel that NGOs have too much influence
Natura key EU biodiversity mechanism		Other EU policies in opposition
Responsibility on Member State to resource		No additional resources provided

Slightly modified, Credit:

www.iucn.org/parks 79

**THE EUROPEAN NATURA 2000 PROTECTED
AREA APPROACH: A PRACTITIONER'S
PERSPECTIVE**

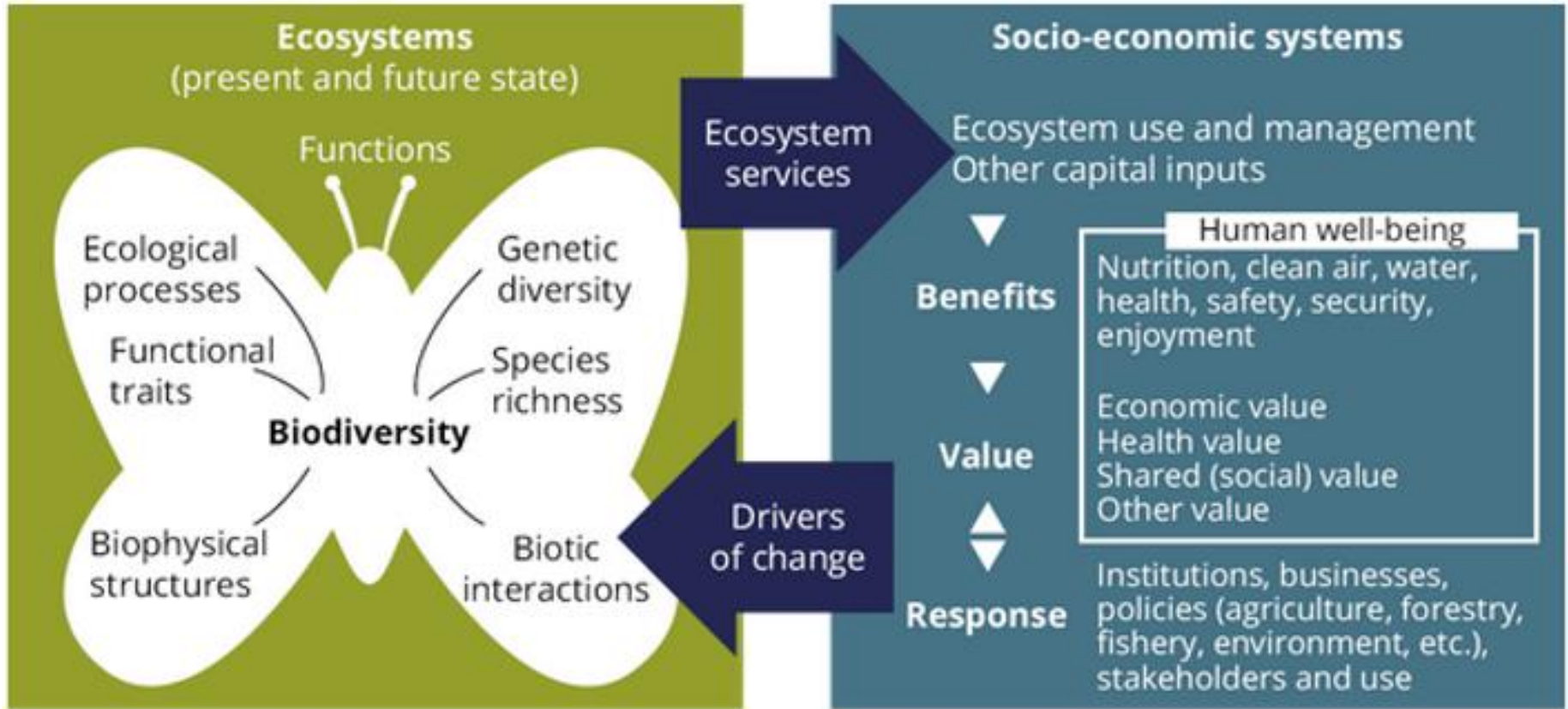
Roger Crofts ^{2*}

PARKS VOL 20.1 MARCH 2014

Protected Areas

- are subject to changing environmental conditions and anthropogenic pressures;
- their management strategies, size, boundaries and protection status will presumably require significant updating in the near future;
- new geographical areas may need to become protected (at a level to be defined) (, for example to host plant and/or animal populations that moved their distribution range in response to climate change and human pressures);
- At the same time, existing PAs may require a significant revision of the management and protection policies (, to account for emergent challenges and to find optimal compromises between conservation requirements and social/economical needs).

ECOPOTENTIAL will address these aspects of future PAs.



Source: Maes et al., 2013.

Maes, J., Teller, A., Erhard, M., Liqueste, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., et.al., 2013, Mapping and assessment of ecosystems and their services — An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020, ©European Union.



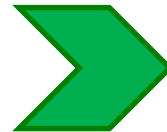
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Services & Pressures
(examples for mountain, arid/ semi-arid and coastal ecosystems)

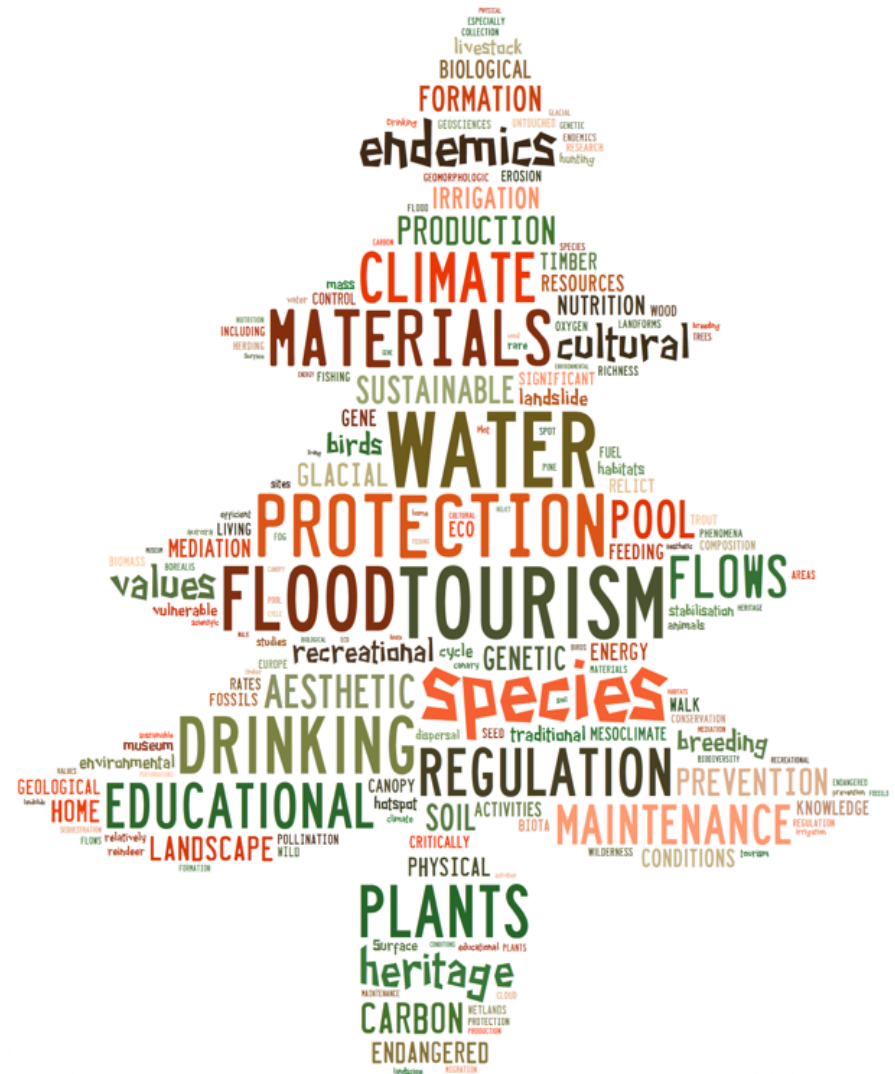


Mountain ecosystems are rich in endemic and endangered species and directly linked to downstream regions

Benefits are identified for watersheds, slope stability, discharge regulation, food and energy production, recreational services and options for tourism.

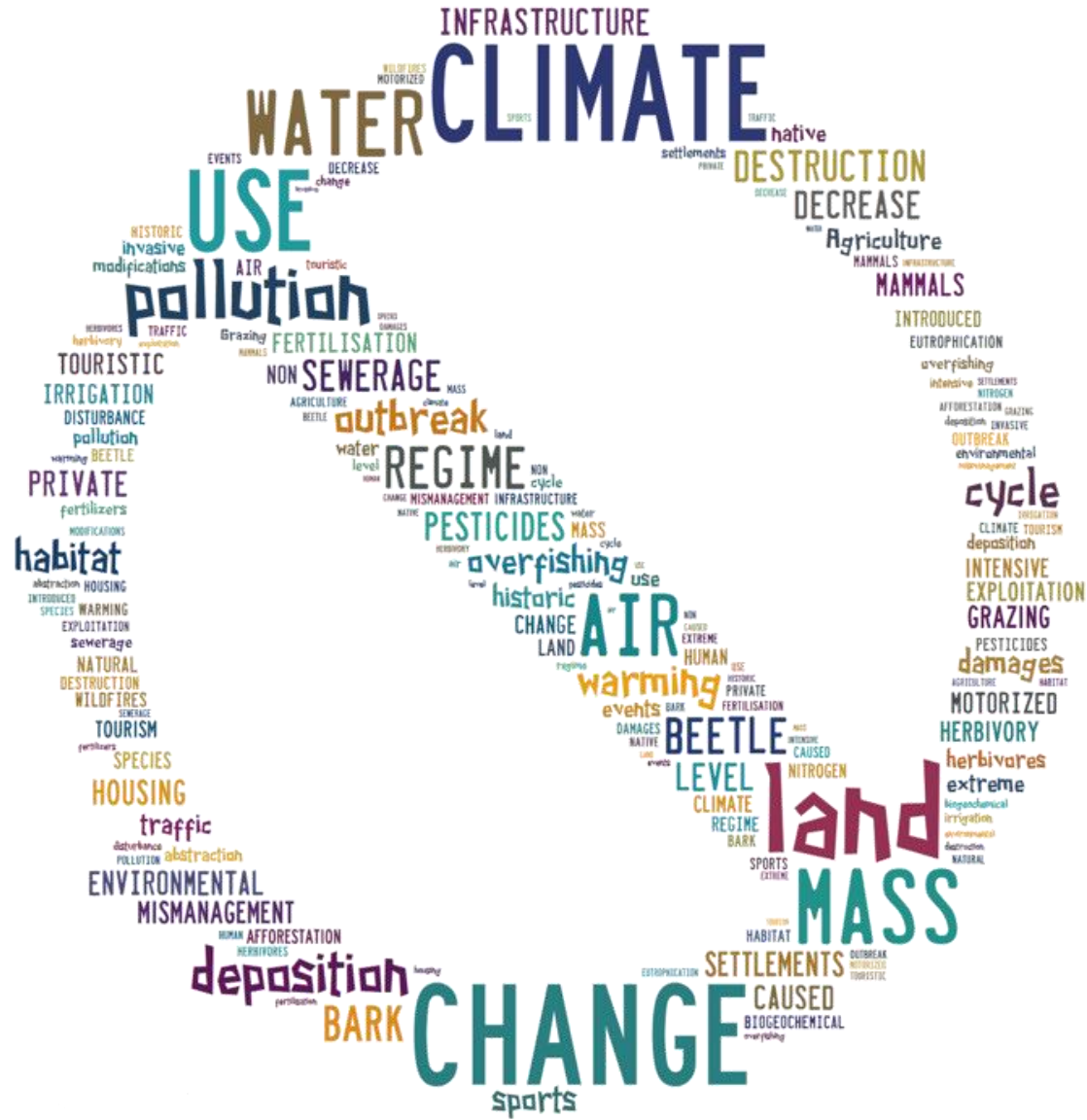
The **spatial heterogeneity of mountains exhibits methodological challenges for EO (cloudiness, shade, etc.)** making these areas excellent training grounds for the development of robust approaches.

In Europe, mountainous PAs of international value exist in all climatic zones and latitudes.



Mountain ecosystems are "sentinels of change" as they are highly sensitive to the impacts of modifications associated with climate and/or land-use change.

The role of mountain regions has been acknowledged at the UN Conference Rio+20, and GEO has recently established the Global Network for Observations and information in Mountain Environments (GEO-GNOME).



Coastal/marine ecosystems are “an integrated and essential component of the Earth’s ecosystem and are critical to sustaining it”*

Coastal areas are transition zones between ecosystems, that are of extreme importance for biodiversity and for the exchange, migration, and refuge of species with complex habitat requirements.

They require for representative approaches that focus on capturing the mobility of organisms within and between ecosystems.

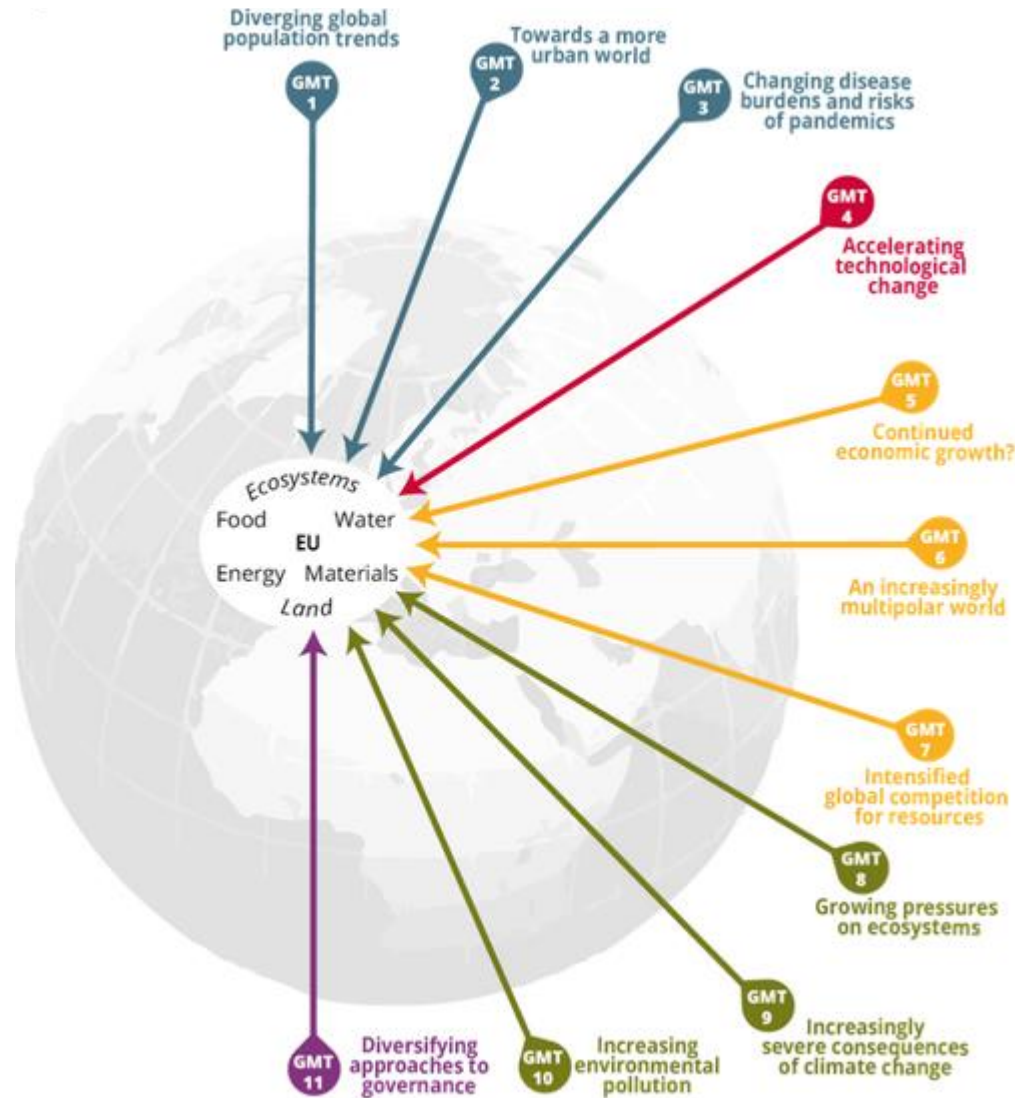


*(Rio+20 outcome document *The Future We Want*, 2012)

Rio+20 also noted that the health of oceans and marine biodiversity are negatively affected by the **impact of human activities**, leading to a loss of biodiversity, decreased abundance of species, damage to habitats and loss of ecological functions and ultimately, ecosystem services.

Countering these threats is **only possible** through sustained monitoring and development of indicators to inform policy makers and coastal/marine managers.





1. Population trends
2. Urbanization
3. Diseases
4. Global competition for resources
5. Climate change
6. Governance frameworks

CREDIT: THE EUROPEAN ENVIRONMENT
STATE AND OUTLOOK 2015
SYNTHESIS REPORT
European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark





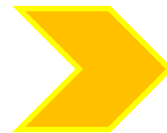
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EO LC products for ecosystem monitoring





International acknowledgement of the role of LC products for ecosystem monitoring



Strategic Goals

CBD headline indicators

Aichi Targets:
following the
Strategic Plan
for
Biodiversity by
the United
Nations (UN),
Convention on
Biological
Diversity
(CBD)

	Strategic Goals	CBD headline indicators
A	4. Sustainability	(4) Pressure practices, (5) Pressures various
B	5. Habitat loss	(1) Extent, (4) Pressures practices, (5) Pressures Various
	7. Agriculture, forest and aquaculture	(4) Pressures practices
	8. Pollution	(5) Pressures various
	9. Alien species	(2) Species, (5) Pressures various
C	11. Protected areas	(11) Protected areas
	12. Threatened species	(2) Species
	13. Genetic diversity	
D	14. Ecosystem services	(6) Services, (11) Protected areas
	15. Climate change resilience	(6) Services, (11) Protected areas
E	17. National BD Strategies & Action Plans	
	18. Indigenous knowledge	
	19. Knowledge Sharing	

Land Cover products contribute to 13 out of 20 targets, as acknowledged by



Numerous studies exist for RS products performance in service of CBD indicators estimation

CBD indicators	Methods	Algorithms																				
		Features					Data processing															
Extent	Forest	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Various veg.	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	LC / habitat	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Degrad. / deforest.	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Fragment.	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Freshwater	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Services	Food	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Raw material	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Water	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Carbon	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Pest control	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Prot. areas	Habitat conserv.	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲

Mapping (shape)

- ▲ Visual interpret. class.
- ▲ Supervised class.
- ▼ Unsupervised class.
- ▼ Rule-based class.
- Linear regression
- ◆ Non-linear regression
- Spectral unmixing
- ▼ Forward/Inv. modell.
- Change detection
- Correlation analysis

Data (inner/outer layer)

- ▲ Passive sensor
- ▲ Active sensor
- ▲ Both

Accuracy (filling color)

- ▲ Upper tertile
- ▲ Mid tertile
- ▲ Lower tertile
- ▲ Non-comparable

Species	Alien
	Indigenous
	Birds
	Fishes
	Mammals
	Invertebrates
Press. Practices	Agriculture
	Forestry
Press. Various	Climate
	Pollution

Z. Petrou, I. Manakos, T. Stathaki, "Remote sensing for biodiversity monitoring: A review of methods for biodiversity indicator extraction and assessment of progress towards international targets", 2015, Biodiversity and Conservation, 24(10), 2333-2363.



European Nature Information System (EUNIS)

EUNIS is a comprehensive pan-European system to **facilitate the harmonized description and collection of data across Europe through the use of criteria for habitat identification**. It is hierarchical and covers all types of habitat types from natural to artificial, from terrestrial to freshwater and marine.

Mapping and Assessment of Ecosystems and their Services (MAES)

MAES aims to **demonstrate the effectiveness of mapping and assessment of ecosystems and their services in planning and land management**. Ecosystems are mapped by interpreting available land cover (LC) data on the basis of the European habitat classification (EUNIS).

Links to **General Habitat Categories** and **Annex I** ones are established within EU projects

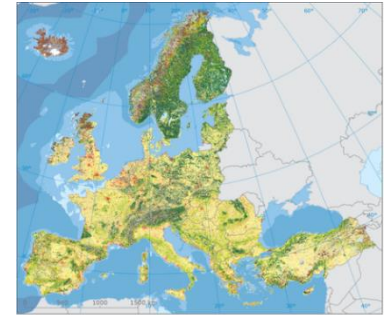
Links to **LCCS of FAO**, as well:

V. Kosmidou, Z. Petrou, R.G.H. Bunce, C.A. Mucher, R.H.G. Jongman, M.M. Bogers, R.M. Lucas, V. Tomaselli, P. Blonda, E. Padoa-Schioppa, I. Manakos, M. Petrou, "Harmonization of the Land Cover Classification System (LCCS) with the General Habitat Categories (GHC) classification system", 2014, Ecol. Indic. 36, 290–300.

M. Adamo, C. Tarantino, V. Tomaselli, V. Kosmidou, Z. Petrou, I. Manakos, R.M. Lucas, C.A. Mucher, G. Veronico, C. Marangi, V. De Pasquale, P. Blonda, "Expert knowledge for translating land cover/use maps to General Habitat Categories (GHC)", 2014, Landscape Ecol., 29(6), 1045-1067.

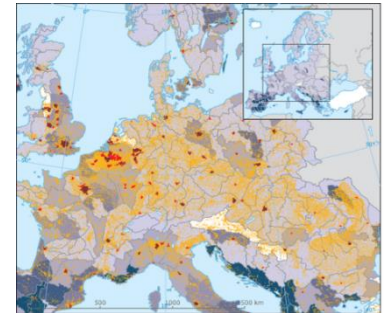
Ecosystem type map

European ecosystem map covering spatially explicit ecosystem types for land and freshwater at 1 ha spatial resolution. Ecosystems are mapped by interpreting available land cover data on the basis of the European habitat classification (EUNIS).



Water Exploitation Index plus (WEI+)

The water exploitation index plus (WEI+) compares water use against renewable water resources. The map illustrates the relation between Urban Morphological Zone and the WEI+ at the sub-basin scale for summer months (July, August and September) defined in calendar year.



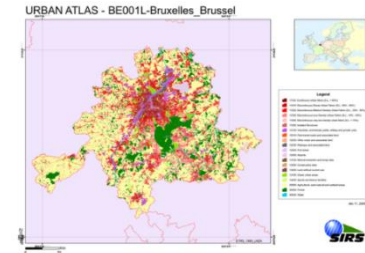
Average annual increase in soil sealing

The map shows the yearly average imperviousness density change, relative to 10 km grid cells. The unit is the average percentage of newly sealed 10 km cells between 2006 and 2009.



Urban Atlas

The Urban Atlas is providing pan-European comparable land use and land cover data for Large Urban Zones with more than 100.000 inhabitants as defined by the Urban Audit.



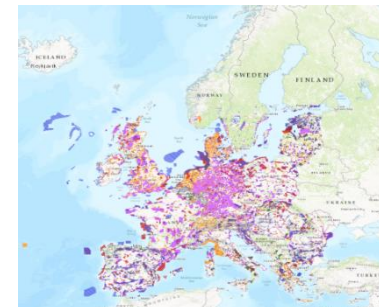
Potential flood risk for European cities from heavy rainfall events

The map highlights some of the conditions which may contribute to urban flooding in Europe.



European protected sites

The map shows an overview of protected sites in Europe, including Natura 2000 sites and nationally designated areas (CDDA).



List is much longer. Please visit the site of EEA.

Figures credit: <http://www.eea.europa.eu/legal/copyright>. Copyright holder: European Environment Agency (EEA)



H2020 and FP7 European projects using EO data for Ecosystem Monitoring (1/3)



EU Project

Earth Observation Application

ECOPOTENTIAL (Improving future ecosystem benefits through earth observations)

<http://www.ecopotential-project.eu/>

Use Earth Observation and field monitoring data, complemented by appropriate interpretation tools, data services and ecosystem models able to use these data for **effective monitoring and modelling of the state and trends in ecosystem conditions and services.**

ERA-PLANET (The European network for observing our changing planet)

www.era-learn.eu/

Provide **advanced decision support tools and technologies aimed to better monitor our global environment** and share the information and knowledge in different domains of EO

GEO-CRADLE (Coordinating and integrating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS)

geocradle.eu/

EO data will be exploited in order to **serve the thematic areas of climate change, improved food security, access to raw materials, and energy.**

ConnectinGEO (Coordinating an Observation Network of Networks EnCompassing satellite and IN-situ to fill the Gaps in European Observations)

www.connectingeo.net/

Enable a European Network of Earth Observation Networks including space-based, airborne and in-situ observations networks to **enhance the use of Earth observations for assessments, forecasts, and predictions of GEOSS SBA topics and Copernicus services.**





H2020 and FP7 European projects using EO data for Ecosystem Monitoring (2/3)



EU Project

Earth Observation Application

SWOS (Satellite-based Wetland Observation Service)

swos-service.eu/

Sentinel satellites will be considered in order to **assess the biodiversity and monitor dynamic changes in an unmatched temporal and spatial resolution.**

EOMonDis (Bringing Earth Observation Services for Monitoring Dynamic Forest Disturbances to the Users)

http://cordis.europa.eu/project/rcn/199830_en.html

Dense time series of optical and SAR satellite data of Sentinel-1 and 2 will be utilized to develop innovative and cost-effective methods addressing the technical challenges for **tropical forest monitoring.**

SEN3APP (Processing lines and operational services combining Sentinel and in-situ data for terrestrial cryosphere and boreal forest zone)

sen3app.fmi.fi/

Sentinel-satellite series were exploited in various task such as: **environmental monitoring, hydrological forecasting and carbon balance assessment.**

BACI (Detecting changes in essential ecosystem and biodiversity properties – towards a Biosphere Atmosphere Change Index)

baci-h2020.eu/index.php/

Existing EOs and downstream products will be synthesized to allow the **detection of changes in land ecosystems, and the attribution of changes to climate and societal transformations.**



H2020 and FP7 European projects using EO data for Ecosystem Monitoring (3/3)



EU Project

Earth Observation Application

BIO_SOS (BIOdiversity Multi-Source Monitoring System: from Space TO Species)

www.biosos.eu/

Issues related to very high spatial EO image processing for **automatic land cover maps updating and change detection** were investigated. Also, a modelling framework, combining multi-scale EO data and in-situ/ancillary data to **provide biodiversity indicators and their trends**, was developed.

UNDESERT (understanding and combating desertification to mitigate its impact on ecosystem services)

www.undesert.neri.dk/

Satellite images were used to **extract indicators that determine the causes and consequences of desertification and degradation processes**.

GEOCARBON (Operational Global Carbon Observing System)

www.geocarbon.net/

The potential for combining satellite imagery information with dense networks of in-situ radiocarbon surface stations for providing **independent verification of fossil fuel emissions** was evaluated.

SenSyF (Sentinels SynergyFramework)

www.sensyf.eu/

Satellite data was used in order to provide services: (a) **generation of land cover and land cover change products**, (b) **arctic-alpine growing season mapping**, (c) **classification of ground as frozen or thawed** and (d) **agriculture irrigation support**.

List grows longer with time and expansion to other funding frameworks



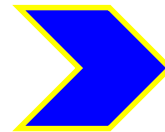
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Challenges faced in the EU





Major challenge in utilizing EO LULC for ecosystem monitoring

Communication amongst scientific communities is sought to support policy making and implementing

Ecology

Remote Sensing

Geography

Computer Science

Finances

Legislation

- Description of land cover and habitat/ ecosystem classes
- Ensure correspondences between both descriptions
- Integration in an operating system
- Field data and local expertise acquisition and incorporation



Major challenge in assimilating EO LULC products for ecosystem monitoring



RS product reliability and adoptability enhancement for the non RS society users (experts and simple users)

Cross-scale

Uncertainty

Processes

Standardization

Interface

Copyrights

- Validation
- Framework conditions analysis and reporting
- Metadata quality
- Easy to access products
- Product delivery maintenance



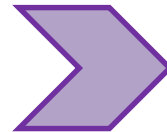
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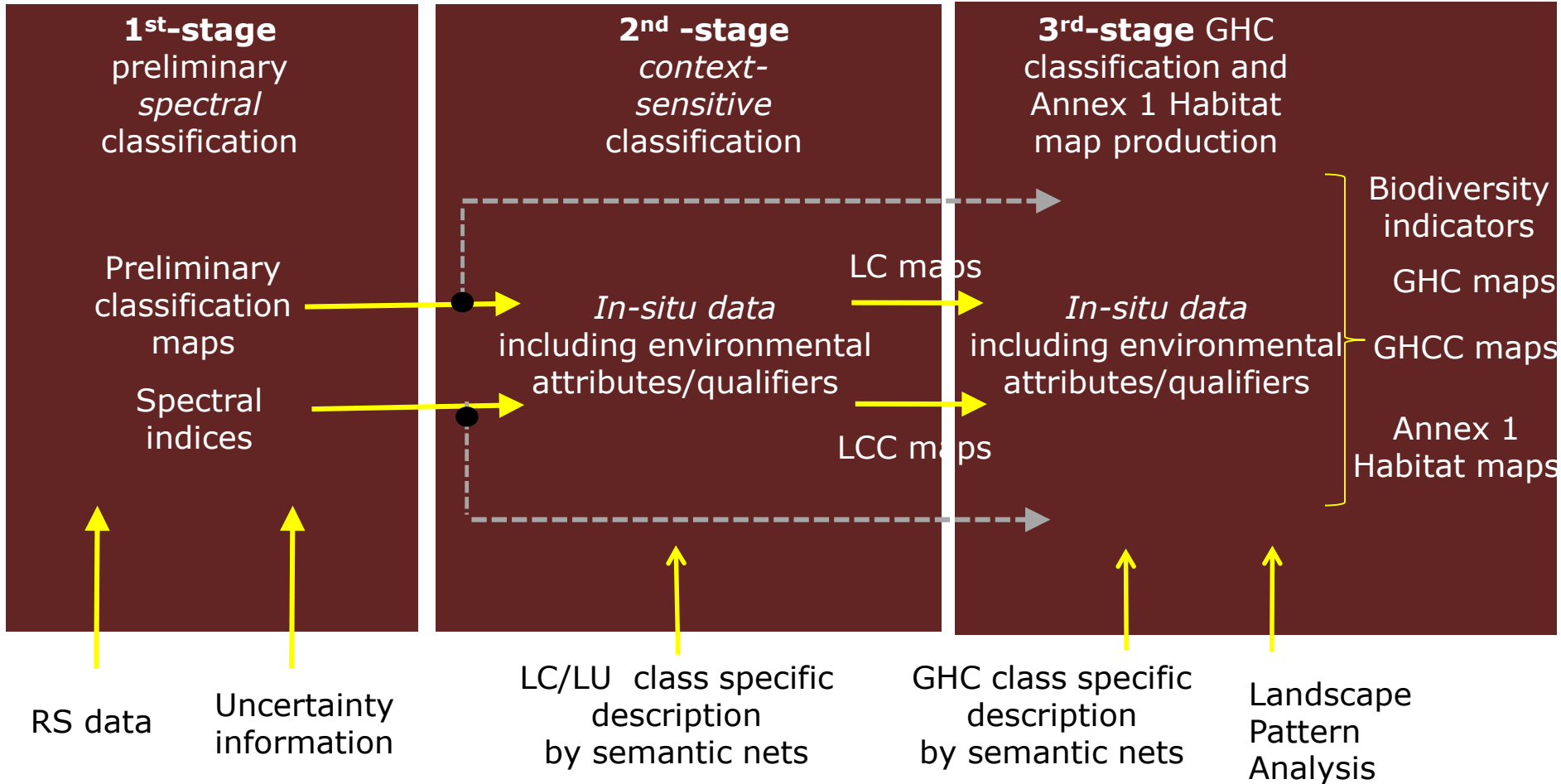
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Towards integrated service platforms
(examples from on going research activities)



Earth Observation Data for Habitat Monitoring - EODHaM



R. Lucas, P. Blonda, P. Bunting, G. Jones, J. Inglada, M. Arias, V. Kosmidou, Z. Petrou, I. Manakos, M. Adamo, R. Charnock, C. Tarantino, C. A. Múcher, R. Jongman, H. Kramer, D. Arvor, J. P. Honrado, P. Mairota, "The Earth Observation Data for Habitat Monitoring (EODHAM) System", 2015, International Journal of Applied Earth Observation and Geoinformation 37, 17–28.

- The Food and Agriculture Organization Land Cover Classification System (FAO_LCCS) is adopted as the classification scheme
- An object oriented approach is adopted within e-Cognition and then translated to open source code along with image pre-processing, segmentation and feature extraction software
- The system adopts deductive learning schemes (i.e., it based on expert knowledge elicitation to fill the gap between domains)
- Ontologies and semantic networks are used:
 - *Domain ontologies* for Land Cover and Land Use (LC/LU) and Habitat class description and LC/LU to Habitats translation;
 - *Task ontologies* for data processing tools description;
 - *Unified Modeling Language* UML language used
- Uncertainty handling through the Dempster-Shafer theory principles

Earth Observation Data for Ecosystem Monitoring

Previous EODHaM system

- Segmentation and attribution
- Rule-based classification using indices and image bands
- Translation to GHCs and Annex 1

Updated EODHaM system*

- ① Refinement of existing rule-based approaches
- ② Integration of existing land cover/habitat maps
- ③ Incorporation of external classifications (e.g., random forests, K means)
- ④ Introduction of sub-pixel proportions
- ⑤ Change detection (LCCS L3/L4 and indices)
- ⑥ Categorisation of processes of change (e.g., deforestation, agricultural expansion, woody shrub decline)
- ⑦ Inclusion of a scoring system that relates change events to impacts on ecosystem services.
- ⑧ Application of an accuracy assessment procedure (TBD).

*Credit: Richard Lucas and Anthea Mitchell
University of New South Wales, Sydney, Australia



Enable the discovery, access, and use of

- open (EO and in-situ monitoring) data, metadata, scientific models and results, semantic engines, and analytics' provision;
- ecosystem models and upscaling methods;
- the necessary knowledge to analyse ecosystems services;
- climate and land-use change scenarios, and definition of the requirements for future protected areas;
- specific applications and portals for different users (e.g. experts, activists, decisions makers), enabling multidisciplinary applications.

All services are empowered by a set of transparent brokering services provided by the platform, as defined in the GEO/GEOSS framework and compliant with the GEOSS Common Infrastructure (GCI) and the GEO Portal ([http:// www.geoportal.org/](http://www.geoportal.org/)).

*Credit: Stefano Nativi, CNR



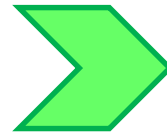
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Towards integrated networking platforms



First joint Workshop of the EARSeL Special Interest Group on Land Use & Land Cover and the



Berlin, March 2014



<http://www.earsel.org/SIG/LULC/index.php>

Timely and thematically coupled with ESA's Living Planet Symposium

Advancing horizons for land cover services entering the big data era

Second joint Workshop of the EARSeL Special Interest Group on Land Use & Land Cover and the NASA LCLUC Program

The Workshop is organized around four representative sessions, covering the latest advances; trending activities and future challenges in land-cover services in the big data era. The four sessions are:

1. Harmonization of Sentinel-2 and Landsat products
2. Mapping Land Cover and Land Use with cross-scale and cross-sensors approaches
3. Challenges of Land Cover and Land Use Monitoring with Dense Time Series of EO Data
4. EO benefits for ecosystem services and human wellbeing

Free open access publication following the normal review procedure at Special Issues of the European Journal of Remote Sensing or the EARSeL eProceedings Journal



EARSeL SIG LULC collaboration with NASA LCLUC Program



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Session Chairs:

Benjamin Koetz, European Space Agency, **ESA-ESRIN**

Hans Dufourmont, Project Manager **Copernicus** Land Monitoring Services

Gary N. Geller, **Group on Earth Observations**

Mutlu Ozdogan, University of Wisconsin-Madison

8 Keynote Speakers:

Jeff Masek, NASA GSFC

Pierre Defourny, University of Louvain

Matt Hansen - Alexandra Tyukavina, University of Maryland

Alexander Prishchepov, University of Copenhagen

Son Nghiem, NASA JPL

Sebastian van der Linden, The Humboldt University of Berlin

Chris Justice, University of Maryland

Palma Blonda, ISSIA, National Research Centre of Italy

Host:

A BIG THANKS to Charles University in Prague, especially Prof. PREMYSL STYCH



Sponsors:





48 prestigious partners across Europe and beyond, across disciplines,
work together for the next 3+ years on
‘Improving Future Ecosystem Benefits through Earth Observation’

Meet us @
<http://ecopotential-project.eu/>



Happy Anniversary LCLUC!!!

With my thanks and appreciation
to **Garik Gutman**
and **LCLUC** for providing us this
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At your disposal for questions/
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