The EAGLE concept – A vision of a future European Land Monitoring Framework

Stephan Arnold[1], Barbara Kosztra[2], Gebhard Banko[3], Geoff Smith[4], Gerard Hazeu[5], Michael Bock[6], and Nuria Valcarcel Sanz[7]

[1]*Federal Statistical Office (DeSTATIS), Wiesbaden, Germany; stephan.arnold@destatis.de*
[2]*Institute of Geodesy, Cartography and Remote Sensing (FÖMI), Budapest, Hungary; kosztra.barbara@fomi.hu*
[3]*Environment Agency Austria (UBA), Vienna, Austria; gebhard.banko@umweltbundesamt.at*
[4]*Specto Natura Ltd., Cambridge, United Kingdom; geoffsmith@specto-natura.co.uk*
[5]*Alterra – Wageningen University and Research Centre, Wageningen, The Netherlands; gerard.hazeu@wur.nl*
[6]*German Aerospace Centre (DLR), Bonn, Germany; michael.bock@dlr.de*
[7]*National Geographic Institute (IGN), Spain, Madrid, Spain; nvalcarcel@fomento.es*

Abstract. This paper describes the EAGLE concept, an object-oriented data model for land monitoring. It highlights the background situation in the field of land monitoring, identifies the team involved, explains the technical and strategic considerations behind the concept, describes the current status of the harmonization and the developments made and outlines the future activities and requirements. After the structure and the content of the data model and matrix are explained, examples are given on how to use the matrix. Besides its possible function as a semantic translation tool between different classification systems, it also can help to analyze class definitions to find semantic gaps, overlaps and inconsistencies and can serve as data model for new mapping initiatives. On the long-term, the EAGLE concept aims at sketching a vision of a future integrated and harmonized European land monitoring system, which is designed to store all kinds of environmentally relevant information on the Earth´s surface, coming from both national and European data sources. Being still in the state of development, some first applications and test cases are under way. This paper also dedicates a chapter referring to the context between the concept and remote sensing in general as well as the relation between land monitoring and the principles of the European Commission´s Horizon 2020 Framework Programme.

Keywords. EAGLE, land monitoring, object-oriented data model, land cover / land use information, bottom-up approach, harmonization, semantic translation

1. Introduction - Current situation of land cover and land use classification in Europe

The multitude of applications of land cover and land use information has over time led to the existence of many classification systems and nomenclatures in the field of land monitoring. Land cover (LC) and land use (LU) are strongly interconnected and they influence each other. For the majority of land monitoring initiatives information on both land cover and land use are important. Therefore most of the existing classification systems contain a pragmatic mixture of land cover and land use information. In addition, each given application may emphasize different aspects of either land cover or land use, related to their specific requirements. Different data collection methods, different scales, narrow tailored-to-purpose definitions, and the lack of completeness for either land cover or land use information make the straight transfer from one application to another not only difficult, but mostly impossible.

In order to improve the flexibility of land monitoring systems to serve both current and future land monitoring initiatives on various scales, the description of landscape by a clear separation of land cover and land use perspective is needed, both in concept and data products. This aspect was also implemented with the separation of the INSPIRE themes Land Cover and Land Use. **Errore. L'origine riferimento non è stata trovata.**

In parallel, responding to the growing need for higher spatial resolution and higher thematic content of data, some European countries have started producing land cover / land use data through national initiatives like for example in AT [3], UK [7], NL **Errore. L'origine riferimento non è stata trovata.** [12], DE [1], ES [25], HU [4], NO [2]. The need for better consistency between national and European data sets and the intention of avoiding redundant data production, has led many of these countries to use their national data to derive pan-European data sets, following the principle of bottom-up approach [14] [23].

Technical and semantic limitations of existing European standards (like CORINE Land Cover - CLC) have also resulted in more and more European countries trying to meet European community data requirements by developing and enhancing their own methods of mapping and data collection. [23] These national activities are currently being used for the production of CLC in a bottom-up way [5].

The information flow generated by these national developments now needs to be integrated with other European "top-down" land monitoring activities such as the Copernicus / GMES GIO Land, and also other European initiatives like the statistical LC/LU field survey LUCAS[1]. All of them can benefit from national bottom-up contributions.

Today the land monitoring community faces the challenge and opportunity to create an integrated data framework that is capable of handling several stakeholders' needs on European level (e.g. EEA and Eurostat) and national level, but also at the same time ensure semantic consistency by harmonizing the data input flow from different national bottom-up approaches. Similar approaches to semantically compare different land cover classification systems are known from literature [15][16][22][24].

2. The EAGLE concept

2.1. Objectives and principles of EAGLE

The EAGLE group (EIONET[2] Action Group on Land monitoring in Europe) was set up by members of EIONET NRCs[3] on land cover as a self-initiated response to the growing need to discuss solutions for a better integration and harmonization of national mapping activities with European land monitoring initiatives (i.e. CLC) at technical level, independently from any political or industry preferences, following the concept of the bottom-up approach.

The objective of the working group is to elaborate a future-oriented conceptual solution that would support a European information capacity for land monitoring built on national data sources combined with pan-European information layers. This can be done by applying the emerging approach of object-oriented data modeling in the field of land monitoring. The group´s conceptual development work is based on initial considerations of how to describe the earth's surface in a conceptual way and how to store that descriptive information related to land cover and land use in a consistent data model.

This led to the following seed questions:

1) What kind of land cover information can be captured with remote sensing data and methods?

[1] LUCAS – Land Use & Cover Area Frame Survey
[2] EIONET - Environmental Information and Observation Network
[3] NRC - National Reference Centre

2) What is in general the ideal way to model landscape under separated perspective of land cover and land use?
3) How to make the data model open for various applications and independent from scale and information source?
4) Is it possible to maintain backward compatibility to existing historical data sets (e.g. CLC time series) after changing the semantic approach without losing information content?
5) How should the term "Object-Oriented Data Model" (OODM) be understood and applied in the context of land monitoring?

The connections to existing standards or code lists were part of those considerations during the development of the EAGLE concept. Such linkages exist between the EAGLE data model and CLC, LUCAS, EUNIS as well as with INSPIRE[4] (especially the themes Land Cover [17], Land Use [19], Buildings [18]) and ISO standard 19144-2 (LCML - Land Cover Meta Language) [21]. Other interrelations with LC/LU-related themes might follow.

2.2. Definition of terms

Land cover is seen as the "physical and biological cover of the Earth's surface including artificial surfaces, agricultural areas, forests, (semi-)natural areas, wetlands, water bodies" in the INSPIRE Directive. **Errore. L'origine riferimento non è stata trovata.** It is an abstraction of reality as the Earth´s surface is actually populated with landscape elements.

The landscape elements are physical features like buildings, roads, trees, plants, water bodies etc. Inside a unit of land, the combination of these landscape elements together with their (bio-) physical characteristics forms the land cover type of that unit. Mapping and describing land cover within a certain classification system, however, usually is different from the mapping of the individual landscape elements and concerned with the portrayal of a continuous surface and not with the individual elements that comprise this surface. In this sense, classified land cover types are to be understood already as an abstraction of the surface [17].

In terms of the EAGLE concept, the abstracted representations of the real world landscape elements, that are relevant for land cover modeling, are called "land cover components". These land cover components are mostly arranged in a typical spatial constellation showing a regionally specific distribution or mixture. In conventional classification systems a name is given to those constellations of land cover components by organizing them in land cover classes, which then can be mapped. The information on land cover components - that form together a class - can either be stored as explicit geometric objects (separate dataset) or implicit as attributive content information attached to land cover classes.

Land use is defined as the "territory characterized according to its current and future planned functional dimension or socio–economic purpose (e.g. residential, industrial, commercial, agricultural, forestry, recreational)" in the INSPIRE Directive **Errore. L'origine riferimento non è stata trovata.**. Land Use (INSPIRE Directive Annex III) [19] is different from Land Cover (INSPIRE Directive Annex II), dedicated to the description of the surface of the Earth by its (bio-) physical characteristics [17].

Land cover and land use are, however, related and often combined in practical applications. Data sets combining land use and land cover often emphasize land use aspects in intensively used areas (e.g. settlements, croplands) and land cover aspects in extensively used areas (e.g. forest, natural vegetation).

[4] INSPIRE – Infrastructure on Spatial Information in the European Community

Landscape characteristics are used as a third important term in the context of the here explained concept. They may contain further property information on a particular land unit and specify it in more detail with some other information that cannot be stored neither under “land cover” nor under “land use”. Further explanation on that is given in the following chapter.

2.3. Structure and content of the data model

The technical aim of the EAGLE group is to provide the conceptual basis for a European data model that 1) separates land cover from land use information and further landscape characteristics, 2) supplies a complete representation of both land cover and land use, and 3) allows the use and integration of information from both national and European datasets to support a European Land Monitoring System.

The main “deliverables” of the EAGLE working group are [9]:

- ***EAGLE matrix****:* A tool for semantic comparison between the class definitions of different classification systems by decomposing them to land cover components, land use attributes and further landscape characteristics, in the form of an Excel table.
- ***EAGLE data model****:* A UML (Unified Modeling Language) model representation of the conceptual data model, visualized in the form of a graphical UML chart. It follows the ISO standard 19109 (Geographic information - Rules for application schema) [20] similar to that applied for INSPIRE.

The two deliverables matrix and model contain the same information and are based on the same considerations and model elements. According to the application purpose the users can decide to either choose to work with the matrix or with the UML-model.

The EAGLE **matrix** itself is subdivided into three blocks standing beside each other. It contains as columns a collection of atomic landscape descriptors of

1.) LAND COVER components - LCC,

2.) LAND USE attributes – LUA,

3.) Landscape CHARACTERISTICS - CH (e.g. land management type, status, spatial pattern, bio-physical characteristics, parameters, ecosystems types).

In the EAGLE model, the basis for the description of landscape are the land cover components that make up a certain land cover class or land surface unit. The LCC are then further characterized by using descriptors listed under “land use attributes” and “characteristics”. They can - and mostly must - be used in combination with each other to describe a specific class or land surface unit. These combinations attached to a certain land cover class of one classification system can be compared with the componential description of a similar class of another classification system. The subdividing of the matrix into those three blocks gives room for flexibility to add / take out / modify some elements of a matrix block without the need to change other parts of the matrix.

The LCC block until the 4th level is structured hierarchically. It is based on the main recognizable pure land cover categories, which are subdivided into their subcategories, the so called Land Cover Components (

Table 1). The components are represented in the tables without any specific relation to attributes or characteristics. The specific relations between the land cover components, land use attributes and their characteristics are visible only in the UML chart. In the original form of the EAGLE matrix the three blocks of LCC, LUA and CH are arranged in columns and all beside each other (from left to right side of matrix). For better readability these three blocks are displayed here separately and shown as rows.

Table 1. LAND COVER COMPONENTS (LCC) of the EAGLE matrix

ABIOTIC / NON-VEGETATED	Artificial Surfaces and Constructions	Sealed	Buildings
			Other Constructions
		Non-Sealed	Waste Materials
			Other Artificial Surfaces
	Natural Material Surface	Consolidated Surface	
		Un-Consolidated Surface	Mineral Fragments
			Bare Soils
			Natural Deposits
BIOTIC / VEGETATION	Woody Vegetation	Trees	Broadleaved Trees
			Coniferous Trees
			Palm Trees
		Bushes, Shrubs	Regular Shrubs
			Dwarf Shrubs
	Herbaceous Plants (grasses and forbs)	Graminaceous (grass-like)	Regular Graminaceous
			Reeds (high growth)
		Non-Graminaceous (forbs, ferns)	
	Succulents and Others		
	Lichens and Mosses	Lichens	
		Mosses	
WATER	Liquid	Inland Water	Water Courses
			Water Bodies
		Coastal Water	Estuaries
			Lagoons
		Open Sea	
	Solid	Permanent Snow	
		Ice and Glaciers	

Likewise, the block of land use attributes is structured hierarchically. Its content represents to a large extend the INSPIRE HILUCS[5] [19] classes (besides some additional modifications). Subtypes are not displayed to their full extension here, only selected subtypes are shown in their entirety (**Table 2**).

Table 2. LAND USE / FUNCTION ATTRIBUTES (LUA) of the EAGLE matrix

PRIMARY Production Sector	Agriculture	Commercial crop production
		Agricultural facilities
		Production for own consumption
	Forestry	Short rotation
		Interim or long rotation
		Continuous cover, selective logging
	Mining and quarrying extraction sites	Surface mining
		Underground mining
		Under water mining
		Salines
	Aquaculture and fishing	
	Other primary production	
SECONDARY Production Sector / Industries	Manufacturing/producing industry	
	Energy production	
TERTIARY Production sector / Services	Commerce, Finances	
	Communication, Information services	
	Accommodation, gastronomy	

[5] HILUCS – Hierarchical INSPIRE Land Use classification system (as proposed in the INSPIRE data specifications for Land Use)

	Community services	Public admininstration, defense, military, secu-
		Science, research, education
		Health and social services
		Religious facility
		Other community services
	Culture, entertainment, recreational	
Transport networks, Logistics, Utilities	Transportation	
	Logistics	
	Utilities	
Residential	Permanent residential	
	Residential-commercial mixed	
	Other residential	
Other Non socio-economic Functions	Inland water functions	Drinking water
		Irrigation
		Fire-fighting
		Reservoir for artificial snow
		Nature protection
		No specific function
	Flood protection (water retention area)	
	Nature protected land	
	Renaturation	
	Abandoned	
	No use, not known, not relevant	

The block of Landscape Characteristics is the most complex and extended one, and can also be displayed here only with its main categories and selective 2nd and 3rd level subtypes (

Table 3). A full representation is meaningful only within the UML chart with its relations to the LCC.

Table 3. LANDSCAPE CHARACTERISTICS (CH) of the EAGLE matrix

Land Management	Agricultural cultivation type	Arable crop land
		Permanent crop land
		Permanent grass land
	Cultivation pattern	Crop rotation
		No crop rotation
		Plantation (intensive)
		Orchards (extensive)
		Agroforestry
		Shifting cultivation
	Cultivation measures	Fertilizing
		Irrigation
		Drainage
		Mowing
		Grazing
		Shrub clearance
	Forest management type	Intensive monoculture
		Regular

		Extensive (selective logging)
	Forest history type	Endemic, primary
		Reforestation
		Afforestation
Spatial Patterns	Texture patterns	Homogenous
		Mosaic
		Scattered
		Mixed, heterogenous
	Linear patterns	Hedge rows
		Tree rows
		Stone walls
		Terraces
	Built-up patterns	Single houses
		Single blocks
		Row houses
		City street blocks
		Large complexes
Crop Type	Arable crops	
	Permanent crops	
	Grass	
Species Type	*Open for any kind of list*	
Mining Product Type	Energy producing materials	
	Metal ores	
	Salt	
	Peat	
	Others	
Habitat / Ecosystem	*e.g. EUNIS classes*	
(Bio-)Physical Characteristics	Abiotic characteristics	Soil sealing degree
	Vegetation characteristics	Leaf type
		Crown cover density
		Phenology
	Water characteristics	Water regime
		Tidal influence
		Water salinity
Status	Under construction	
	In use	
	Out of use	
	Damaged	
	Clear cut	
Temporal parameters	Seasonal changes	Seasonal frequency
		Seasonal duration
	Regular changes	
General parameters	Height	
	Width	

The **data model** is expressed in UML and is visualized in a UML chart. In there, the Land Cover Components listed in the matrix are shown as UML elements and subdivided also into three main branches of UML-classes “ABIOTIC”, “VEGETATION/BIOTIC” and “WATER”. They inherit their properties from the overall "LandCoverUnit", which represents the geometry. Any description of landscape unit or decomposition of a given land cover class (as part of a nomenclature) must start with the selection of a particular LandCoverUnit (one instance). This geometric LandCoverUnit can be made up by one single or several "LandCoverComponents". Under the parent LandCoverComponent, all the instances of LCCs are arranged in a hierarchical way, subdividing into the three main LCC block (Abiotic, Vegetation and Water) with their subtypes.

To those UML-LandCoverUnits other Land Use Attributes can be attached by connecting them with the HILUCS classes. The Land Use attributes are strongly related to the existing proposal of the Hierarchical INSPIRE Land Use Classes (HILUCS) and are not included explicitly in the EAGLE UML chart, but only mentioned through a linked relation.

In addition, the LandCoverUnits respectively the LandCoverComponents can be described with further landscape characteristics. In the UML model the characteristics are handled as enumeration lists or code lists (depending on if they are meant to be closed lists with fixed content or extendable and open for new additional values).

2.4. How to use the matrix/data model

The matrix can be used for description of landscape in threefold ways, starting with the land cover components:

a) The LCCs can be used simply as a kind of nomenclature attaching a single LCC to a certain land cover unit or location.

b) They can be used in a descriptive way, attaching more than one land cover component to a certain land cover unit, expressing that more than one single land cover component exists on a particular patch in landscape.

c) The LCCs can be used in a descriptive way like mentioned in b), but more elaborated by not only mentioning more than one LCC to be attached to a certain land cover unit, but also entering a percentage value, which indicates the relative fraction of the considered land cover component inside a definite land cover unit. This third method of using the matrix is also in line with the concept of the GMES raster products High Resolution Layers (HRLs).

For those methods the encoding of the LCC can be done using a collection of codes that expresses the relevance of the applied matrix elements for the given land cover class (e.g. CLC) to be decomposed or surface unit to be described. Because the encoding result appears as a sequence of values (xx, x, 0, 1, 2, 3, 4) it is called "*Bar Coding*".

Starting with any of the above listed manners (a, b, c), the chosen LCCs then can be further specified by additionally combining them with relevant land use attributes and landscape characteristics.

<u>The collection of usable code lists:</u>

***xx**: The matrix element is not relevant for the class, being logically excluded, therefore not applicable*

***x**: The matrix element must not occur in class, being excluded by class definition*

***0**: The matrix element is insignificant in the class (may still be present due to generalization)*

***1**: The matrix element can be expected in the class but is not a defining element of the class*

***2**: The matrix element is a defining obligatory element of the class and must be present. If more than one matrix element is chosen, at least one of that selection must be present (OR-function).*

***3**: The matrix element is a defining obligatory element of the class and must be present; if more than one element tick-marked then all must be present (cumulative AND-function)*

***4**: The presence of the matrix element is a defining obligatory element of the class and must be present; if more than one element tick-marked then more than one must be present (cumulative multiple AND-function).*

Examples for bar code values:

xx : CLC class 335 (glaciers and perpetual snow) never contain patches of trees, because they cannot survive there

x: CLC class 321 (natural grassland) should never include matrix element 'fertilizing'

0 : CLC class 211 (arable land) might contain small tree patches (LCC=broadleaved trees) due to generalization, but it is not typical of the class.

1 : CLC class 112 (discontinuous urban fabric) must contain vegetation, usually also trees, still there are villages without any trees

2 : CLC class 223 (olive groves) must contain broadleaved trees.

3 : CLC class 313 (mixed forest) must contain both broadleaved trees and coniferous trees

4 : CLC class 242 (complex cultivation patterns) must contain at least two of the three matrix elements from the CH block Crop Types | "arable crops", "permanent crops", "permanent grassland".

In the practical implementation of the matrix, all single classes of a given classification system (e.g. CLC) are represented as lines in the original matrix table. Going through a single class (one line), in every matrix field the relevant matrix element (a LCC or LUA or CH as column) can be tick-marked, if it is present / not present in the class definition, or can be bar-coded to indicate its relation to other matrix elements.

Examples for combinations of LCC, LUA, and CH

I. Parcel of woodland that has been partially damaged by storm:
LCC: coniferous trees; LUA: forestry; CH status: storm damaged

II. Abandoned industrial site:
LCC: specific structures; LUA: raw industrial; CH status: out of use

III. Intertidal flat:
LCC1: Clay, Silt; LCC2: Sand; LUA: not relevant; CH1: tidal influence; CH2: saline water

IV. Village settlement:
LCC1: buildings; LCC2:open sealed surfaces; LCC3: vegetation; LUA1: permanent residential; LUA2: agricultural production for own consumption; CH pattern: discontinuous single houses.

3. Foreseen role, uses and application

3.1. EAGLE matrix/model as a tool for description and harmonization

The EAGLE concept is not meant to be yet another classification system. It shall be understood as a model to describe land units in a feature-oriented manner by decomposing them and pointing out the characteristic landscape elements. The EAGLE matrix is on the one hand a tool for describing a class of a certain land cover classification system by decomposing the class definition into its information 'modules', allowing better understanding of the classes.
This way, the EAGLE matrix can be used for:

1) Analytical understanding of class definitions within a given classification system bydecomposing their information content into LC, LU and other characteristics,
2) Identification of overlaps, gaps and other shortcomings of classes within a given classification system,
3) Separated extraction of LC and LU information from classification systems of

"intermixing" nature, such as CLC,

4) Comparison of entire classification systems (either class by class or as a whole), identification of similarities and differences between the definitions of corresponding classes of different classification systems,
5) Semantic translation between two or more classification systems.

On the other hand it can be used to describe the landscape itself by assigning land cover and land use information and other characteristics to a real land surface unit (polygon, grid cell or sample point), serving as

6) data model for newly captured landscape information.

Rooted in its semantic and modelling capabilities, the matrix / model in the European land monitoring context is capable of

7) Identification of input data requirements and data availability or data gaps regarding any national or European (e.g. CLC, HRLs) land inventory
8) Translation of different national land monitoring data into each other and into European databases (e.g. CLC)
9) Providing a framework for future mapping and data collection initiatives of an enhanced European land monitoring system.

The three main applications of the EAGLE data model / matrix are therefore

A) Analytic decomposition of class definitions,
B) Semantic translation between different classification systems,
C) Data model for newly initiated mapping initiatives.

3.2. Vision of a future European land monitoring scheme

Stepping beyond the semantic and landscape modeling benefits of matrix / model application, the EAGLE concept possesses a great potential as conceptual framework for integration of national and European land monitoring initiatives.

The state of land surface has on the one hand a substantial effect on the state of the environment and human well-being; on the other hand it serves as indicator of a multitude of natural and anthropogenic processes. Sustainable management of the land resources on local, regional, continental and global level requires regularly updated, reliable and comparable information on land use and land cover. Land monitoring activities are the procedures that can provide the needed thematic information by human interpretation and computerized analysis of Earth Observation (EO) data and its integration with in-situ data. Data provided by land monitoring systems serve the needs of environmental monitoring and management, landscape management, spatial planning, nature conservation, agriculture, forestry, water catchment management, to mention only a few examples from a multitude of applications.

In spite of its importance, land monitoring in Europe is still far from exploiting the potential laying within the capabilities of involved actors and the quality of input information available on different levels. Lack of harmonization between national and European land monitoring schemes leads to inefficient use of resources and to mismatching of products. Also, the thematic overlap of user requirements for the same kind of data on different institutional levels in coexistence with restricted access to that specific information leads to redundant data production. At the same time, the emergence of new technologies, information resources and the need for more detailed environmental information are challenging the current European system, which is often unable to give timely response to these challenges due to its complexity and inflexibility. Recognizing the disorganized situation of land monitoring in Europe from the conceptual point of view has led to the self-initiative of experts founding the EAGLE group.

The EAGLE concept envisions the EAGLE matrix / model as the center piece of a interconnecting harmonized European Land Monitoring Framework (ELMF). In this vision the Framework constitutes a data collection, harmonization and re-distribution interface between (sub-)national and European levels. (Figure 1) Data flow from national initiatives fills up a central envelope (data model), where data are decomposed to their information modules (matrix items), and then elementary or re-composed information is re-distributed to fulfill needs of European users. Similarly, European products flowing into the envelope can fulfill data need on lower level. The EAGLE data model, as the exchange interface between initiatives also ensures compliance with INSPIRE (LC and LU themes).

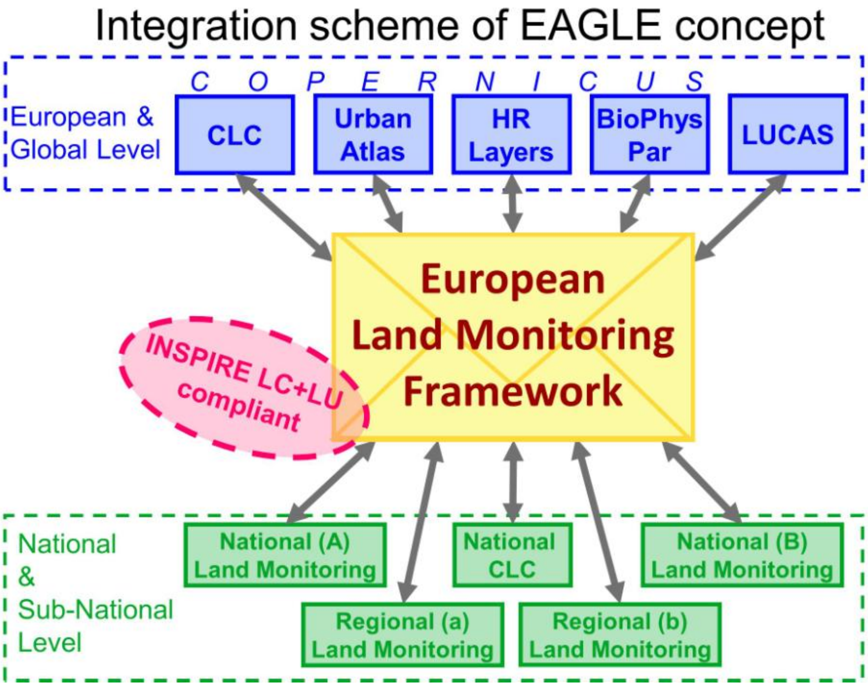

Figure 1. The scheme of the European Land Monitoring Framework as envisioned by the EAGLE concept

Putting the ELMF into practice would help to improve European land monitoring through:

- Harmonization between national and European data,
- Provision of more detailed information on the environment,
- Resource-efficiency thus avoiding duplication of work and efforts,
- Independency from reference year related timelines of particular dataset update cycles,
- Flexibility to user needs on information content for creating better usable down-stream products,
- Supporting a multi-track approach (combination of conventional data production and implementation of new concept), adapted to capacities and national spatial data infrastructures of participating countries,
- Fostering a closer cooperation between the land monitoring and the statistical

community.

Beneficiaries of concept´s implementation would be

- European Community, its institutional bodies (e.g. DGs ENV, CLIMA, AGRI; EEA, ESTAT) and citizens (better products for lower cost on the long run),
- Member States (no need to duplicate efforts regarding European / international reporting duties, harmonization between national and European data),
- Statistical institutions (semantic translation tool for land use accounting).

3.3. Connection with HELM project

The vision of EAGLE´s integrated land monitoring system is at the moment incorporated under the umbrella of the HELM (Harmonizing European Land Monitoring), an FP7 funded pan-European project [13]. The project consortium comprises a network of national and European authorities and institutions concerned with land monitoring. From almost every European country representatives are involved. It embraces an even wider circle of land monitoring experts, practically every EAGLE member is also partner of the HELM consortium, among some additional partners. The project was set up for the time window 2011 – 2013 and encompasses a work package[6] dedicated to the development of a European data model based on the contribution and achievements of the EAGLE group.

The scope of HELM is to create a platform for exchange of expertise and best practices and to initiate a move to increase the maturity of European land monitoring. It envisions a coherent European land monitoring system characterized by high quality data and efficient productivity. This system will combine the broad range of specific expertise and resources of relevant authorities in the member states. Their work will be supported through targeted centrally supplied measures fulfilling common requirements for raw data and data processing.[7]

4. Context with remote sensing

The EAGLE matrix defines a large amount of descriptive information to characterise landscape units and allocate them to a selected nomenclature. Some of this information can be derived from remote sensing / Earth Observation (EO) if it has a recordable surface expression, either at a particular time or via a dynamic change. The opportunities to use EO data as source of information for the EAGLE matrix are concentrated in the land cover components (LCC) and the characteristic (CH) section.

The information that can be derived from EO data will depend on the specifications of the images such as spatial and temporal resolution (number of images available) and spectral information content. In general terms, when working in the European landscape at least high spatial resolution (HR: 10 – 30 m pixels) is required to capture the field and city block scale structure. However, for some characteristics in the EAGLE matrix such as cultivation patterns and linear elements it will be necessary to use very high spatial resolution (VHR: down to sub-metre) data to capture the narrow features. Still medium resolution data (MR: 30 – 300 m) is very valuable to derive information in the temporal domain as MR-sensors have shorter revisit cycles to cover a location on ground in shorter time intervals.

[6] Task 4.3 Work out basic criteria for a Europe-wide nomenclature/data model for land monitoring

[7] See also SEVENTH FRAMEWORK PROGRAMME THEME [SPA.2010.1.1-06] [Coordination of national activities for land monitoring] Grant agreement for: Coordination and support action Annex I - "Description of Work (DoW)"

Temporal Resolution defines the number of images available within one year (multi-seasonal) and / or several years (multi-annual). With multi-seasonal imagery the phenology of vegetated surfaces, agricultural cultivation patterns and measures, as well as seasonal changes of water regimes can be captured. In principle, increasing the number of images during one single vegetation period in combination with the right timing of its acquisition also helps to increase the detectability of growth development of crops and other vegetation in general and helps to distinguish between them.

The spectral information content of the EO data is related to the number and range of spectral bands that are recorded. The majority of optical systems record in the visible and near infrared (NIR) wavelengths, however those that also record in the shortwave infrared (SWIR) offer greater discriminating power, especially regarding vegetation. Microwave and LiDAR systems can provide additional information on surface structure and canopy properties. Also RADAR data can contribute to land monitoring procedures in general and vegetation type detection in particular. Some methods have been developed through scientific activities, but their entire operational potential has not yet been unfolded completely.

In the land cover section of the EAGLE matrix EO will be able to discriminate quite easily between the abiotic, biotic and water surfaces as they have distinct spectral responses.

The separation of abiotic artificial and abiotic natural surfaces may be in some cases more challenging spectrally as the materials involved could be similar thus requiring spatial information on texture and pattern. For instance the roofs of buildings, concrete surfaces and artificial bare ground could have similar spectral properties to bare rock and mineral fragments and soils. Artificial surfaces tend to have a more homogenous character or show regular patterns and can therefore be separated from the irregular patterning of natural surfaces. Further subdivision of the abiotic group will depend on the spatial resolution of the EO data relative to the surface features and the spectral separation of the actual surface materials involved.

The biotic group offers more opportunities for the exploitation of EO data due to the variety of spectral responses, spatial patterns and temporal behavior produced by the range of pigment proportions, leaf and canopy structures, and growth forms of vegetation. The most detailed discriminations of vegetation will be produced when SWIR bands are recorded and multiple dates within the same growing season are available. In these cases it may be possible to get down to species level for some of the vegetation types. A new perspective in the field of plant species detection is also opened by hyper-spectral sensors. However, a countrywide application for the time being seems to be beyond affordable costs. Therefore multi-temporal availability of imagery is still the key for differentiation of different vegetation species types. The upcoming SENTINEL-2 satellite programme will provide freely available information on phenological developments every 2-3 days with a resolution of 10*10m from 2014 onwards.

The water group can be easily divided into solid and liquid types due to their very different spectral properties. When subdividing the liquid phase then a continuum exists been relatively clear inland lakes and highly turbid coastal waters which can be measured. Both inland and coastal water surfaces may rely on context and feature shape for a reliable identification into a referring land cover type.

The land use section is dominated by functional types that in many cases cannot be identified directly from EO data through automatic image analysis. Rather the shapes of a features or certain detectable patterns give indications on the land use. Therefore extraction of LU information from RS data is still very much dependent on experienced visual image interpretation. The EO data may indicate buildings, but their use is impossible to identify from the spectral and spatial information alone. The functional types of apparently obvious features such as airports cannot be guaranteed as they might be abandoned and may change their use. For instance, abandoned airfields often become industrial (storage and production) or recreational (motor sport) or open air museum sites but appear the same in EO data.

In the final section of the EAGLE matrix EO data can support a large number of the characteristics. For instance, vegetation properties such as crown cover density can be extracted from the spectral response as is being done operationally in the GIO Forest layer. Other characteristics related to phenology and temporal dynamics can be inferred from multi-date EO data. The identification of linear features or fine scale patterns (like hedge rows, stone walls, small ditches) will require VHR data to be effectively detected.

In summary, EO data has a great potential to help characterize landscape features with the land cover components and characteristic elements of the EAGLE matrix. The actual level of capability will depend of the EO data itself, the timing of the image acquisition(s) and the features being characterized. Given a particular sensor it would be possible to derive a subset of the EAGLE matrix which it can support, and given a particular land cover or characteristic within the EAGLE matrix it will be possible to select one or more suitable sensors and acquisition specifications.

5. Outlook

5.1. First applications and testing

A first operational application of the model on European level is being implemented under the umbrella of EEA's European Topic Centre on Spatial Information and Analysis (ETC-SIA) as a subtask under the Implementation Plan 2013, where also members of the EAGLE group are involved. In this task the EAGLE concept is used for revealing gaps and inconsistencies of CLC nomenclature, by decomposing class descriptions to land cover, land use and characteristic components with help of EAGLE matrix. Using these results, a proposal for an enhancement of CLC nomenclature guidelines is foreseen to be given to EEA. Enhanced class definitions will help a more consistent harmonized CLC production (both with traditional photo-interpretation and bottom-up/semi-automated methods).

Internally, the matrix bar coding method has also been applied on Eurostat´s LUCAS LC classes, and EEA´s CLC classes. The group is in constant contact with those stakeholders.

On regional level, some land monitoring initiatives are about to test the EAGLE data model on the applicability for their purposes.

5.2. Further steps

So far, a first draft of the concept is put in place. Still, it is a conceptual work in progress and at this stage it will constantly be further developed and enhanced. It is intended to be tested for operational functioning as part of the sketched framework, also some synchronization actions on the legal, institutional and technical field have to be considered.

The current status of the EAGLE matrix / model has reached a level of maturity that allows for testing on real databases.

For the long-term perspective, the EAGLE group has worked out a list of work packages to further develop the concept. Besides the fine tuning of the model, it also contains the development of an online tool to populate the matrix and use it as a comparison tool (matrix population and comparison tool - MPCT) among others.

5.3. Module idea

The EAGLE model and matrix in its full extent and at its present state has reached a quite complex form. The attempt to describe all kinds of landscape types that may occur in Europe has led to this state. However, with regards to potential users who are not yet familiar with object-oriented data modeling practices, or only need to focus on landscape from a specific thematic point of view, it can be considered to tailor the model for just those fields of work and take out other parts of the model that are not needed. The model can be designed for specific monitoring purposes e.g. for agriculture or forestry or urban areas. In that case, only the thematically relevant model elements (under the Land Use Attributes and the further Characteristics) could be compiled, others can be left out. By reducing the complexity of the model, it might gain in attractiveness for application.

5.4. Relation between future land monitoring and Horizon 2020 principles

The symposium´s heading motto “Horizon 2020 - Earth Observation and Social Perspectives" can be connected with the work of the EAGLE group. The Horizon 2020 Framework Programme for Research and Innovation of the European Commission [10] aims at helping to address “major concerns shared by all Europeans such as climate change, sustainable transport and mobility, renewable energy [a.o.]”.

“Horizon 2020 will focus resources on three distinct – yet mutually reinforcing – priorities, where there is clear added value to the European Union:

- Excellent Science
- Industrial Leadership
- Societal Challenges

The ‘societal challenges’ reflects the policy priorities of the Europe 2020 growth strategy and addresses major concerns shared by citizens in Europe and elsewhere. It embraces and will focus on the following fields of work:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture, marine and maritime research and the bio-economy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, resource efficiency and raw materials;
- Inclusive, innovative and secure societies.”

As a general statement the Horizon 2020 Framework Programme claims to have sustainable development and environmental concerns as overarching objectives. Further, on a long-term perspective one resource efficiency target is to reduce the net land consumption in the EU to zero by the year 2050.

All of these challenges need a working system of monitoring and assessment, 2nd to 5th issue listed above are strongly connected with spatial information and rely on them. Important tools for building up such kinds of monitoring systems are provided by remote sensing and GIS methodologies. The engagement of the land monitoring community and the exploitation and development of their standards and protocols will be vital to achieve the aims of Horizon 2020.

6. Conclusions

The EAGLE concept

1) can be a useful framework for the integration of LC / LU information from various datasets in one single data model.
2) is applicable on both national and European level.
3) is a vehicle for comparison and semantic translation between different LC/LUnomenclatures, and facilitates data exchange.
4) is open to be implemented as a LC / LU data collection standard for national land

monitoring initiatives.

5) can be a coherent common data framework for several single GMES products (CLC, HRLs, Urban Atlas).
6) has been developed on a voluntary basis by EAGLE members, independent from any political or industry preferences with its origin in a MS experts' initiative.

A common European framework for land monitoring, which is able to connect semantically several data sets of land cover and foster information interchange, can only be of benefit for the social perspective of Earth observation (background of data flow exchange, monitoring of valuable natural protected sites, food supply and harvest monitoring, quick reaction on disasters etc.).

Very sophisticated methods have already been developed and tested, but their application on big scale is in many cases beyond affordable budget of responsible institutions. As a message from the land monitoring community, an appealing signal shall go out to the scientific community for continuation of their very much appreciated and essentially needed research and development activities in favor of further development of efficient methods that are applicable and transferrable from research test cases to the national or pan-European scale.

Acknowledgements

The EAGLE group was founded upon a self-initiative of land monitoring experts from various European countries, mainly in their function as NRCs for land cover under the umbrella of EEA's Eionet.

The EAGLE concept in its current form is the result of a joint voluntary work of the group. The group members work and meet on a voluntary basis, not financed by any external budget, except the home institutions seconding them to the working group meetings. Support to the group has been given by the FP7 geoland2 project and the FP7 HELM project through covering travel expenses. Secretariat service and chair persons were provided by European Topic Centre on Spatial Information and Analysis (ETC-SIA).

The Authors would like to acknowledge the contribution of all other EAGLE members, namely Cristoph Perger (Austria), Tomas Soukup (Czech Republic), Markus Törmä and Elise Järvenpää (Finland), Stefan Kleeschulte and Andreas Littkopf (Germany), Gergely Maucha and György Büttner (Hungary), Geir-Harald Strand (Norway), Mario Caetano (Portugal), Alejandro Simon Colina, Guillermo Villa and Roger Milego (Spain), Charlotte Steinmeier (Switzerland).

References

[1] Arnold, S., Busch A. & Grünreich, D., 2010. *Das Projekt DLM-DE2009 Landbedeckung*. Mitteilungen des Bundesamtes für Kartographie und Geodäsie 45. Arbeitsgruppe Automation in Kartographie, Photogrammetrie und GIS (AgA) Tagung 2009, 9-22.
Arnold, S., Bock, M.,Feigenspan, S., 2014. *Digital Land Cover Model for Germany DLM DE – The "German Way".* In: Manakos, I. & Braun, M., 2014 (in preparation). *Land use and land cover in Europe: practice and trends*. Remote Sensing and Digital Image Processing Series. Springer.

[2] Aune-Lundberg, L. & Strand, G.-H., 2010. *CORINE Land Cover 2006 - The Norwegian CLC2006 project.* Report from Norwegian Forest and Landscape Institute 11/2010.

[3] Banko, G., Franzen, M., Ressl, C., Riedl, M., Mansberger, R. & Grillmayer, R. 2013. *Bodenbedeckung und Landnutzung in Österreich – Umsetzung des Projektes LISA zur Schaffung einer nationalen Geodateninfrastruktur für Landmonitoring.* Strobl, Blaschke, Griesebner, Zagl (Hrsg.): Beiträge zum 25. AGIT Symposium Salzburg, S. AGIT 2013, 14-19.

[4] Büttner, G., Maucha, G., Bíró, M., Kosztra, B., Pataki, R. & Petrik, O., 2004. *National land cover database at scale 1:50,000 in Hungary*. EARSeL eProceedings 3(3), 323-330.
[5] Büttner, G., Kosztra, B., Maucha, G. & Pataki, R., 2010. *Implementation and Achievements of CLC2006*, Final Draft. ETC-LUSI document.
[6] CBS NL, 2008. Centraal Bureau voor de Statistiek - Statistics Netherlands. *Bodemgebruik Nederland BBG2008*. URL:http://www.cbs.nl/nl-NL/menu/themas/dossiers/nederland-regionaal/cijfers/cartografische-toegang/geoviewer.htm .
[7] Centre for Ecology & Hydrology – CEH, 2011. Land Cover Map 2007 Dataset documentation, version 1.0
[8] European Commission, 2007. *Directive 2007/2/EC of the European Parliament and of the Council establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).*
[9] EAGLE – EIONET Action Group on Land Monitoring in Europe. URL: http://sia.eionet.europa.eu/EAGLE
[10] European Commission, 2011. *COM (2011) 808 final version. Horizon 2020 - The Framework Programme for Research and Innovation.* Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions.
[11] Feranec, J., Büttner, G. & Jaffrain, G., 2006. *CORINE Land Cover nomenclature – Illustrated guide* (revised Addendum 2000). ETC-LUSI document.
[12] Hazeu, G.W., Bregt, A.K., de Wit, A.J.W & Clevers, J.G.P.W., 2011. *A Dutch multi-date land use database: Identification of real and methodological changes*. International Journal of Applied Earth Observation and Geoinformation 13, 682–689.
[13] HELM (FP7 project) – Harmonising European Land Monitoring. URL: http://www.fp7helm.eu/ .
[14] HELM (FP7 project), 2012. *Panorama of European Land Monitoring*. Deliverable task 1.1 report .
[15] Herold, M., Woodcock, C.E., & al., 2006. *A joint initiative for harmonization and validation of land cover datasets*. IEEE Transactions on Geoscience and Remote Sensing 44(7), 1719-1727.
[16] Herold, M., Hubald, R. & Di Gregorio, A., 2009. *Translating and evaluating land cover legends using the UN Land Cover Classification System (LCCS)*. GOFC-GOLD Report No. 43. Jena, Germany.
[17] INSPIRE, 2013. D2.8.II.2 *Data Specification on Land cover* – Draft Technical Guidelines version 3 (Identifier D2.8.II.2_v3.0rc3).
[18] INSPIRE, 2013. D2.8.III.2 *Data Specification on Buildings* – Draft Technical Guidelines version 3 (Identifier D2.8.III.2_v3.0rc3).
[19] INSPIRE, 2013. D2.8.III.4 *Data Specification on Land use* – Draft Technical Guidelines version 3 (Identifier D2.8.III.4_v3.0rc3).
[20] ISO (2005): ISO 19109:2005(E). *Geographic information - Rules for application schema*.
[21] ISO (2012): ISO 19144-2:2012. *Geographic information - Classification systems* - Part 2: Land Cover Meta Language (LCML).
[22] Jansen, L., Groom, G. *et al.*, 2008. *Land-cover harmonisation and semantic similarity: Some methodological issues*. Journal of Land Use Science 3(2-3), 131-160.
[23] Manakos, I. & Braun, M., 2014 (in preparation). *Land use and land cover in Europe: practice and trends*. Remote Sensing and Digital Image Processing Series. Springer.
[24] Neumann, K., Herold M., & al., 2007. Comparative assessment of CORINE2000 and GLC2000. *Spatial analysis of land cover data for Europe.* International Journal of Applied Earth Observation and Geoinformation 9(4), 425-437.
[25] Valcarcel, N., Villa G., Arozarena A., Garcia-Asensio, L., Caballero, M. E., Porcuna, A., Domenech, E. & J.J. Peces, 2008. *SIOSE – a successful test bench towards harmonization and integration of land cover / use information as environmental reference data* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing 2008.