


HELM

Harmonised European Land Monitoring





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Findings and Recommendations of the HELM Project

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HELM – Harmonised European Land Monitoring

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HELM aims to increase productivity of European land monitoring by improving alignment between national and sub-national land monitoring endeavours as well as by enabling their integration into a coherent pan-European data system.

The Coordination and Support Action HELM, funded under the 7th Framework Programme of the European Commission, started in January 2011 and ended in December 2013. The acronym “HELM” stands for ‘Harmonised European Land Monitoring’.

Contributors: Contributions were made by the entire HELM Consortium and by some members of the HELM Extended Consortium.

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Abbreviations & Acronyms

ALS	Airborne Laser Scanning
ATKIS Basis-DLM	Authoritative Topographic-Cartographic Information System´s Basic Digital Landscape Model
CAPI	Computer Assisted Photointerpretation (software)
CH	Characteristics
CLC	CORINE Land Cover
CLCXXXX	CORINE Land Cover for the specified year (e.g., CLC2000 for the year 2000)
CORINE	Coordination of Information on the Environment
DLM-DE	Digital Land Cover Model for Germany
EAGLE	EIONET Action Group on Land Monitoring in Europe
EEA	European Environment Agency
EIONET	European Environment Information and Observation Network
EO	Earth Observation
EU	European Union
EUNIS	European Nature Information System
FAO	Food and Agriculture Organisation of the United Nations
GEO	Groups on Earth Observations
GIO	GMES Initial Operations
GIS	Geographic Information System
GMES	Global Monitoring for Environment and Security
HELM	Harmonised European Land Monitoring
HRL	High Resolution Layer
INSPIRE	Infrastructure for Spatial Information in the European Community
ISO	International Organisation for Standardisation
LAEA	Lambert Azimuthal Equal-Area (projection)
LCC	Land Cover Component
LCCS	Land Cover Classification System
LCML	Land Cover Meta Language
LISA	Land Information System Austria
LM	Land Monitoring
LMA	Land Monitoring Activity
LPIS	Land Parcel Identification System
LUA	Land Use Attributes
LUCAS	Land Use and Cover Area Frame Survey
LULC	Land Use and Land Cover
LCU	Land Cover Unit
NFI	National Forest Inventory
QA	Quality Assessment
QC	Quality Control
SBE	State Boundaries of Europe
SDI	Spatial Data Infrastructure
SEIS	Shared Environmental Information System
SIOSE	Land Cover and Use Information System of Spain
UML	Unified Modelling Language

Contents

Executive Summary

The HELM Project

Four chapters follow in this book: Background, Challenges, Foresight, and Conclusion – What's Next. The first chapter, Background, takes stock of land monitoring practices in European countries. The second chapter, Challenges, relates a range of issues encountered with land monitoring as it is currently practised and how such matters can be better resolved through improved collaboration. Building upon these findings, the third chapter, Foresight, outlines the HELM (Harmonised European Land Monitoring) roadmap towards a mature, integrated pan-European land monitoring system based upon aggregated national data which are supplemented by centrally produced base data. The concluding chapter, What's Next, sets the HELM project and its recommendations in context.

Background

The overview of European land monitoring shows what already exists and how we got there. The European Union (EU) land monitoring activity storyline covers all major pertinent activities, programmes, projects, and bodies while showing how this topic had evolved over the last two decades. This documentation provides the basis for all other outcomes of HELM as it aligns common knowledge and delineates the activities that should be considered when designing an integrated European land monitoring system.

Societal Implications points at why we want to monitor land to begin with, exposing different – not always compatible – interests that are its major drivers. While some of these interests can be foreign to the primary motivation underlying land monitoring they should not be ignored when aggregation approaches are designed, particularly when considering the impartiality of final data products. Currently, European citisens are hardly involved in designing and using land monitoring outcomes although political implications of the data may have a significant influence on their everyday lives.

Several pioneering activities already apply **Cross-Border Cooperation and Decentralised Approaches** thereby taking advantage of multi-national or regional partnerships. Numerous initiatives have already emerged to compare and harmonise land monitoring data in several European countries at their borders, because environmental issues are not confined to one country alone. Moreover, in some countries where a federal system is established bottom-up data aggregation is already practised based on provincial or regional and national datasets. Both cases provide invaluable lessons learnt that can be applied in the design of a pan-European land monitoring system that is based on aggregated national data.

Challenges

Current issues in practical land monitoring can most easily be addressed by **Considering Best Practices in Europe**, namely, proven solutions which have already been shown to work in one country, which are transferable to other countries, and which clearly illustrate the added value of professional collaboration. Such practices relate primarily to cost/benefit aspects, data applications and their legislative requirements, comparison of parameters, and the driving forces behind land monitoring systems.

The land monitoring endeavours currently practiced in various countries have evolved independently of each other. Our investigation of **Operational Commonalities, Gaps, and Differences** shows that indeed, they differ significantly in several regards yet at the same time they also exhibit many similarities that could provide a sound basis for collaboration.

Considering the similarities in the logic driving land monitoring in various European countries and the technical approaches taken by them, **Common Needs and Tasks** can be articulated in terms of suitable means that either jointly tackle or are supported by a central source. Such common needs involve the acquisition and (pre-) processing of data, human and technical and scientific capacity, including IT, measures to ascertain the quality of derived data products, and broad sharing of experiences and knowledge.

Foresight

The HELM perspective as to how European land monitoring should be arranged in the future is based upon **Common Strategic Views**. Both decentralised, i.e., bottom-up, and centralised, i.e., top-down, land monitoring data provision each have clear advantages and disadvantages. A future European integrated land monitoring system would do well to combine the advantages of both approaches so that the needs of users, whether individuals, communities, or nations, are addressed alike in an economically efficient manner.

Emerging from our findings is the need for aligned national land monitoring activities where the many different datasets are linked and combined between and across administrative levels while allowing for the freedom of data interpretation needed at the regional and national scales. We offer the **EAGLE[1] Concept** which can be used both to translate between different existing land classification systems and as the basis for designing new ones, thereby providing the foundation to aggregated national data originating in the different European systems in a bottom-up fashion.

HELM envisages a bilateral flow of data between different agencies involved in European land monitoring activities in that the aggregated national land data production should be supplemented by a central component of the system which delivers **Future Copernicus[2] Products Supporting (Sub-) National Land Monitoring**.

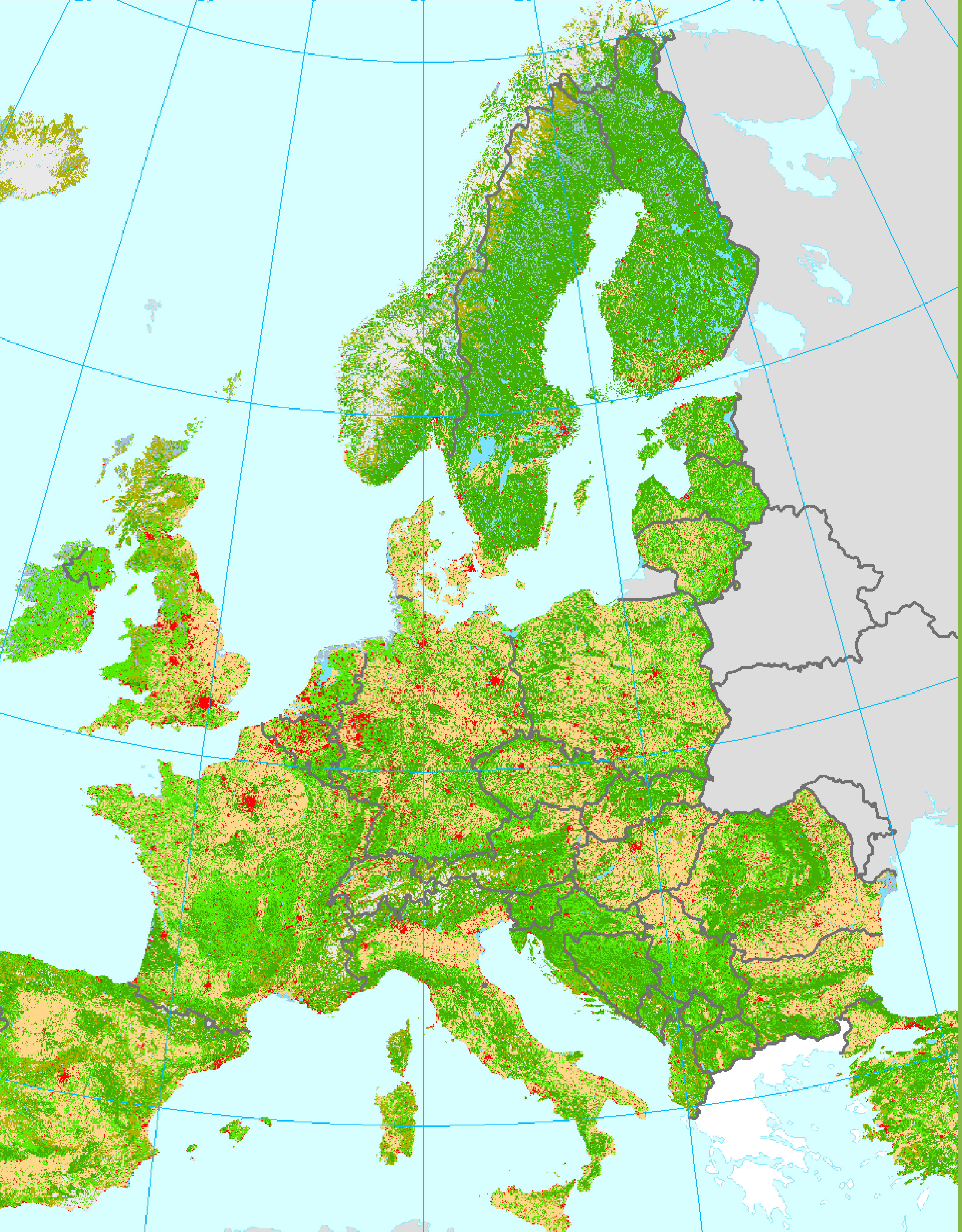
A major aspect regarding this aggregation of data from various sources can be seen in **Database Merging Techniques** that encompass not only remote sensing data, but also data from other sources. The overall process consists of the integration of existing data into a production database and, subsequently, their aggregation to harmonised land monitoring data. More importantly, professional database merging techniques support the SEIS[3] principle and they can simplify the process of drawing European datasets from a multitude of national ones.

The need arises to adjust both the spatial and thematic contents of data, as well as time frames defining when such data are gathered in the different countries so that an overall **Synchronisation** is achieved between inter- and intra- national agencies as well as pan-European agencies. There is no one optimal timing for all data gathering campaigns. Such timing depends on the scale of end products because more detailed maps must be updated more often than coarser ones. Timing would also depend on content because some landscape features, such as cities, change more rapidly than others, such as forests.

When redesigning European land monitoring, possible **Alternative Approaches** to land monitoring should be considered. Data can be presented as irregular polygons that adhere to certain landscape features (the current incumbent approach) or as regular cells independent of the landscape they describe. Both must still be supplemented by a map legend or description of map contents. Presenting and describing data in square cells that resemble a grid appears to have most potential for becoming the most suitable approach to combine data from separate European countries in order to handle them at the European level.

All these considerations lead to novel **Perspectives for European Land Monitoring**, an overall outlook as to how European land monitoring should be shaped in the future. This development would begin with agreements across European political levels and lead to a reliable and sustainable land monitoring process, in line with INSPIRE[4] and including clear quality assurance procedures. As a precondition for this process, the existing pan-European land monitoring activities will have to develop into, or even be replaced by, a modernised successor that can accommodate all constituents of the HELM roadmap.

1 EIONET Action Group on Land Monitoring in Europe, where EIONET stands for European Environment Information and Observation Network.
2 Copernicus, is the European Programme aimed at establishing a European capacity for Earth Observation.
3 Shared Environmental Information System.
4 Infrastructure for Spatial Information in the European Community.



Introduction

Introducing Harmonised European Land Monitoring

Monitoring of Land Use and Land Cover (LULC) and their evolving nature is among the most fundamental environmental survey efforts required to support policy development and effective environmental management. Nevertheless, land monitoring (LM) is not, as yet, well organised across the different administrative levels within European countries. It is characterised by inefficiency, ongoing development, and use of workarounds necessary for the delivery of the most basic LULC needs.

Although there is no compulsory regulation of land monitoring procedures in the EU or in Europe's environmental context, these data play a key role in a large part of European environmental directives and regulations. Many current environmental issues are directly related to the land surface, such as habitats, biodiversity, species phenology and distribution, ecosystem services and soil degradation, as well as many issues related to climate change.

The same holds true for the human impact on the environment transpiring through settlements, transport, tourism, industrial infrastructure, soil sealing, agriculture, and forestry, to name but a few. The state of the land surface is a crucial ecological factor, an essential – almost non-renewable – economic resource, and a key societal determinant as it influences the population's opportunities for dwelling, work and recreation, the structure of rural and urban societies and, not least, nations' sense of identity. Land thus plays a central role in all three factors of sustainable development: ecology, economy, and society.

Land monitoring in Europe is currently undergoing significant changes. To a certain degree, land monitoring products are still produced independently of each other at the global, European, national and sub-national levels. Such diversity leads to reduced interoperability and duplication of work, and thereby, inefficient use of resources. Several member states conduct land monitoring with varying levels of sophistication and longevity and a broad spectrum of commitment and expertise ranging from countries that have adopted state-of-the-art technology and standards to those conducting virtually no land monitoring. To date, only some member states are collaborating, and to a limited degree only, which has led to partial correspondence of intra-country land monitoring activities and restricted joining of forces.

HELM is an important step aimed at improving the urgently needed overall coordination of land monitoring between European countries with the goal of producing better mutual understanding and stronger collaboration between pertinent organisations and individuals, improved alignment between land monitoring activities of countries represented in the project, and paving the way towards aggregation of national and sub-national land-related data towards pan-European data systems. Consequently, the project was a participatory endeavour based on highly interactive work and focused communication procedures, enabling all parties to be heard, to raise their wishes and concerns, to reflect upon each other, and to create mutually agreed upon outcomes. Compared to the existing Copernicus Earth Observation (EO) system, HELM takes the opportunity to address many of these issues and to move towards increased harmonisation.

This report provides the essence of the HELM work which span three years. It is intended to provide an overview of the outcomes and, not least, to whet the reader's appetite to learn more about specific land monitoring matters by consulting the original project deliverables, downloadable from the project website: www.fp7HELM.eu.

Background

Overview of European Land Monitoring

HELM deals, primarily, with the exchange of knowledge. Its first goal was to achieve panoramic, common knowledge and understanding of the evolution of the European land monitoring activity in the past few decades, at least among all stakeholders participating in the HELM project. This activity prompted an overview of the history of land monitoring in Europe, highlighting how the most important concepts evolved along with a comprehensive catalogue portraying land monitoring activities as developed in member states as well as at sub-national level. This overview provided the basis upon which a clear picture could be established of the current situation, including, as well, a final analysis of who-is-who in land monitoring. At the same time, potential improvements that should be considered when designing an integrated European land monitoring system were covered.

History of land monitoring in Europe

Based on the need to contextualise HELM objectives and outcomes in a broader framework, a critical analysis has been undertaken of previous work pertaining to the development of land monitoring at European level since the agreement to produce the CORINE[5] land cover in 1985. This required a thorough examination of the evolution of concepts and technologies, as well as ongoing workshops, discussion groups, and relevant projects. Consequently, the HELM consortium was able to build upon existing infrastructures and practices thereby avoiding repetitive, redundant work in the project.

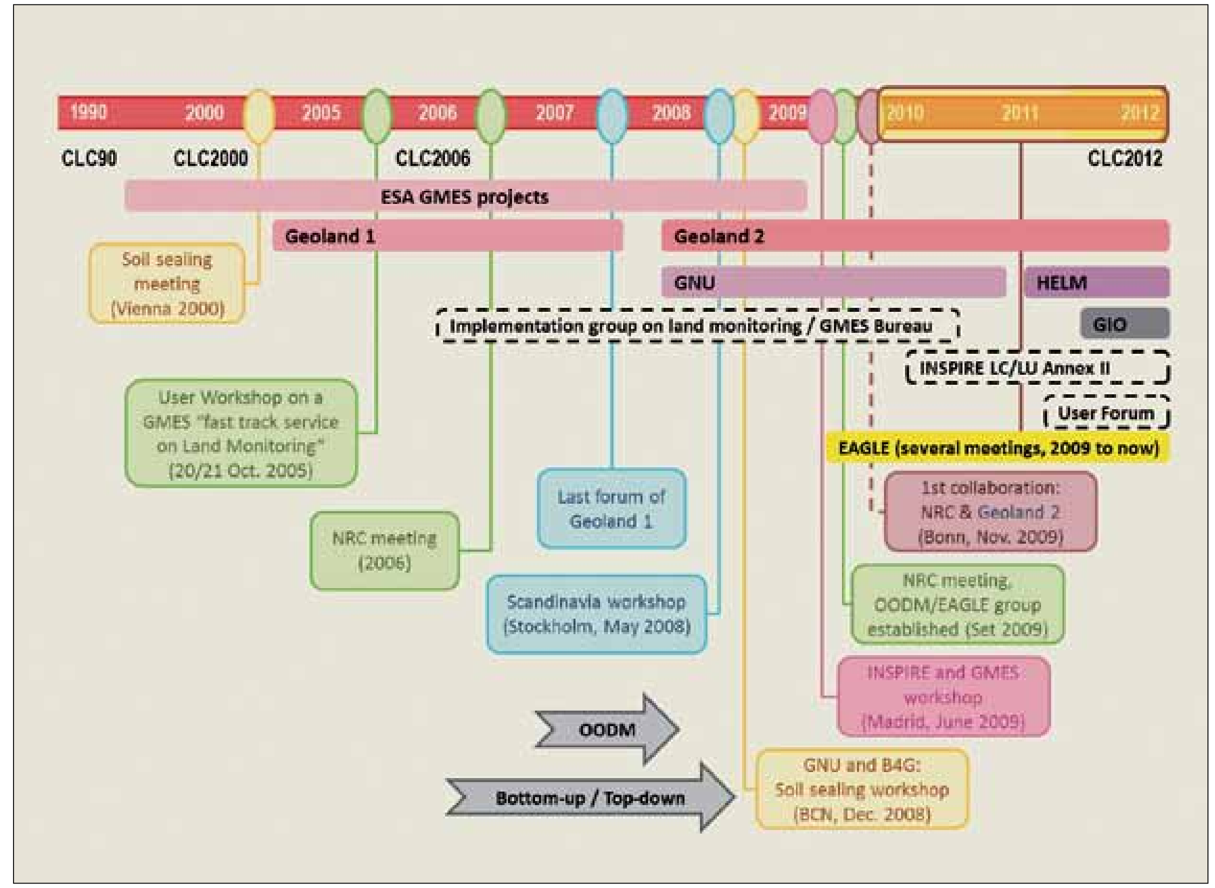


Figure 1. Timeline schema of the European land monitoring activity

The EU land monitoring activity storyline shown in Figure 1 summarises the main critical items and steps that have influenced the development of the European land monitoring activity, such as different initiatives, communications, outcomes from several projects, etc. Delineating all these initiatives served to achieve an improved product and appropriate data model for land monitoring at the pan-European level while also incorporating needs expressed by member states that ought to be part and parcel of the ultimate goal of land monitoring.

In its current state, European land monitoring efforts comprise different products developed at different scales by different administration bodies. To streamline resources and generate an effective land monitoring system in Europe, it would be important to combine bottom-up and top-down approaches so as to make the best use of products at both national and pan-European level. The combination would enable the extraction of added value from national products within a

5 Standing for Coordination of Information on the Environment, the CORINE programme was initiated by the EU in 1985. The programme maintains a number of databases including an inventory of land cover and land use (CLC), produced operationally for most areas of Europe on a 6 to 10 year cycle.

standardised pan-European framework for information on land cover and use and would guide the delivery of useful basic parameters from the European level.

Lack of comparability and difficulties in harmonisation of the different products due to varying scales and originating agencies create serious problems when trying to combine initiatives. Several EU-funded land monitoring projects (the GMES[6] programme among them) have endeavoured to overcome this difficulty by proposing, for an unspecified set of end users, a set of services based on EO satellite data, harmonised and comparable across Europe.

Similarly, several initiatives handled at the national level have focused on building national land monitoring activities alongside the CORINE land cover (CLC) programme. These explored the potential of obtaining a pan-European land monitoring dataset through the harmonisation and merger of data developed at country or regional levels.

Nonetheless, the final approach to be followed is yet to be agreed upon among all the stakeholders participating in the process. It would have to be based on their willingness to develop a useful structure for land monitoring at EU level while relying on sincere communication and coordination that actively involve all the stakeholders in the development, testing and validation of a new EU-scale land monitoring programme.

Documentation of land monitoring activities at the level of EU member states

Using expert knowledge present within the HELM consortium, documentation of land monitoring activities as developed at the levels of both EU member states and sub-national regions has enabled the compilation of a who-is-who directory of the land monitoring stakeholder community and the mapping of initiatives conducted at the different spatial levels. As a result, a summary contextualising the assessment and interpretation of the different cases within the various member states has been produced.

Information needed for this task was collected by means of a fact sheet. It allowed for a delineation of those important organisations that are responsible for land monitoring in each country as well as the main land monitoring initiatives in that country. Where sub-national organisations or initiatives significantly contributed to the land monitoring setup in a particular country, respondents were asked to also describe such organisations and initiatives. The fact sheet was distributed amongst HELM participants (general and extended consortium). Responding was part of the required project work for the general consortium and voluntary for the extended consortium. Responses were compiled into a directory that can be consulted in the deliverable resulting from this activity.

In addition to the country approaches, for organisations operating at the European and global level and for initiatives implemented at both levels, further fact sheets were completed. These data were based on knowledge available within the HELM consortium while also originating from information offered on the Web. Results from Eurostat's LUCAS (the Land Use and Cover Area Frame Survey), were also used to provide information, about the land monitoring organisations as well as initiatives not covered by the HELM partners.

The fact sheet was mostly focused on spatially explicit polygon mapping approaches such as those used in CLC where each polygon represents a landscape unit, excluding sampling and statistics-based land monitoring approaches (e.g., forest inventories) which would usually not result in maps. This approach evolved from the *Objects of Consideration* as defined for the HELM project. The national representatives within HELM were also allowed to include organisations and initiatives which they considered would provide the necessary background to produce an overview of the land monitoring situation in their country.

6 Standing for Global Monitoring for Environment and Security, which since 2012 was renamed as the Copernicus programme.

Societal Implications

Monitoring of land resources is of great importance for a wide range of purposes, including spatial planning, nature conservation, urban development, and the evaluation of impacts pertaining to soil degradation, availability of water for agriculture, and so on. It serves to assess future potential uses of land and its sustainability which constitutes a decisive factor regarding the state of the environment and human wellbeing. Hence, the main goal of the HELM project, concentrating on turning European land monitoring more productive, environmentally friendly, and most of all – human friendly. This would be achieved through better alignment of national and sub-national land monitoring endeavours while enabling integration of these two levels into a coherent European LULC data system.

Key messages

- Multiplicity of individual interests must always be kept in mind
- 'Foreign' interests impact efficiency, cross-border coordination, and impartiality of land monitoring at EC, national, and sub-national levels
- Citizen and public involvement is confined to informal political processes at local levels only
- Pull/push factors in migration patterns must be considered in both current and future land monitoring policies

One area that must be taken into account in this process is the societal implications of land monitoring efforts in Europe. The main focus of investigation in this arena encompasses the following:

- Exploration of an array of important political, social, and economic factors that are influential in the context of land monitoring enterprises while examining their implications and effectiveness;
- Exposure of trends and motivations behind land monitoring practices;
- Identification of obstacles, socioeconomic situations, and 'foreign' interests that potentially impact the efficiency, cross-border coordination, and impartiality of land monitoring at pan-European, national, and sub-national levels;
- Identification and analysis of 'persuasive' powers of indirectly involved parties who exert their influences on the initiation, research, and ultimate outcome of land monitoring endeavours through a variety of methods aiming at achieving the adoption of specific policies in land use that would serve them economically or otherwise (e.g., for conservation purposes);
- Highlighting the current state of citizenry involvement and exploration of ways by which such public participation could be increased.

All of these factors could have far-reaching impacts and implications on the increasing maturity of European land monitoring and the overall goal of the HELM project. They also affect citizens and society beyond the scope of land use regardless of the extent of citizenship involvement.

Political factors

An examination of political factors that influence land monitoring initiatives shows great variety of authoritative levels, responsibilities and motives. This variance poses considerable barriers to policy implementations, especially at European level , the chief among them being the incomparability of data due to different LULC classification systems across Europe and within applicable levels.

Currently, no standard classification system exists that is accepted for international purpose or use in the EU other than CORINE. Dataset and source heterogeneity, gaps in availability, lack of harmonisation of datasets at different scales, duplication of information, and loss of time and resources when searching for the required data are all prevalent deficiencies currently characterising the European situation in land monitoring and spatial planning obstructing any potential for efficient application and use across the continent.

Foreign interest and ‘persuasive power’

An attempt has been made to identify the areas and factors that enable ‘foreign’ interest to exercise influence on the decision-making process pertaining to land use, whether covering up bad practices, involving labour or other services in the monitoring process, or generating economic (or other) gains from specific land use, planning, and monitoring processes.

Several literature reviews touched on the ‘persuasive power’ of private sectors and interest groups in determining and influencing the outcomes of grant selection processes, dissemination of results, and thereafter – the monitoring process. As a result, such persuasive parties exert influence over the adoption of policies to the effect of eventually enhancing their dominance and access over land resources and markets (either for economic motives or other ends, such as enhancing protection of land for conservation or establishing open land purposes). To achieve this, these parties seek to influence the political process through technological monopolisation, funding of scientific research and sponsoring programmes (thus also threatening academic freedom), political pressure, raising of public awareness, and lobbying in political processes. Even though this argument is well established, many private organisations still attempt in their effort to produce research and policy statements.

The level of ‘foreign’ interest influence is significantly greater in weaker economies or transitional states, where land governance and evaluation systems are not yet established or where a central agenda might be lacking or not followed. As a result, with local governments setting their own agendas which also entail required investment, private sector entities such as value-adding companies have greater chances to influence municipal (and also higher-level) land-related decisions.

Economic factors

Socioeconomic considerations play a vital role in the overall purpose and outcome of land monitoring policies. Economic factors such as the value of urban land, urban land take, and mass tourism have been identified as main forces behind landscape changes in Europe. Behind the immediate transformations in land use hidden players and influences are contributing to this trend.

Naturally, such influences must be examined when initiating land monitoring. Authorities should learn to maintain the fine balance between economic gains from urban land take, such as industrial zoning or economic rejuvenation or profit from tourist development with the often-negative ecological and environmental impacts of land conversion.

Social trends

One of the social aspects that are brought to light in the literature review – albeit at a limited scope – is the dual effect of land use alteration resulting from migration. The dual effect encompasses both the area of origin of migrants and their new areas of residence. Changes may occur in areas where migrants have come from, such as rural land abandonment. They can also be significant in places to which emigrants have travelled, such as an increase in density of population and of multi-tenant houses. Therefore, social policies and land use policies cannot be viewed as two separate aspects, where migration is concerned – in both the abandoned and the absorbing areas.

A consideration for the existence of pull/push factors in migration patterns is essential in both current and future land monitoring policies. With this in mind, more emphasis should be placed on the socioeconomic make up of settlements. Difference in behaviour, population ethnicity, demand for job, and lifestyles can all play a role in migration patterns distinguishing native and migrating populations in areas such as living environment, transportation, clean air, rural setting, urban-rural relationships, or counter urbanisation.

Citizenry involvement

All levels of government recognise the need for public participation. To a certain degree they also encourage it. In reality, however, our investigation demonstrates that levels of citizenry interest, involvement and influence in land monitoring activities vary widely from one country to another, rarely reaching beyond regional administrative levels.

Citizenry interest in getting involved in land monitoring that affects aspects of their lives is present and constantly needed. However, due to legislative framework and lack of publicity, the levels of actual involvement and the importance placed on public opinions are restricted to informal political processes and to municipal or local levels only. No public involvement is present at the formal initialisation, operational, or implementation stages of land monitoring. Increased public awareness, increased access to resulting data and other land monitoring initiatives, and more local involvement in bottom-up approaches, could enhance the public’s input (and participation) serving as a valuable source of information for higher-level land monitoring activities.

Cross-Border Cooperation and Decentralised Approaches

The situation and conditions of land monitoring vary significantly across European countries. Monitoring initiatives at both national and sub-national (federal government or local) levels can be identified in several European countries. Among these are some successful examples of intergovernmental bottom-up cooperation within the country.

Numerous initiatives have emerged at the national level aiming to compare and harmonise border-related land monitoring activities in several European countries. Figure 2 shows where some cross-border cooperation takes place between European regions.

Understanding the pillars of these successful cooperative models, both cross-border and bottom-up, is essential for designing future sustainable pan-European land monitoring plans. These must take into consideration the prevailing diversity of administrative, economic, and even cultural and social situations while avoiding duplicity of efforts and harmonising existing data for further European analysis and exchange.

Key messages

- Long-term land monitoring at the European level requires both commitment and predictable funding
- Roles and responsibilities must be clearly defined by participating organisations in bottom-up cooperation
- Financing is a key factor as an incentive in establishing cooperation between agencies
- Cross-border cooperation would result in cost savings

Cross-border cooperation

Several European mechanisms and programmes have been developed to financially support cross-border activities, but it seems that none caters for long-term land monitoring activities at sub-national, national, or even European level that would systematically cover cross-border issues. Existing cross-border cooperation is sporadic, and in most cases it is financed or co-financed by the European Commission, the United Nations, INTERREG IVC[7], and their likes. These ad-hoc projects, however, lack the long-time commitment as well as predictable funding which are required for a sustainable land monitoring programme.

Existing cross-border cooperation and harmonisation initiatives relevant to the field of land monitoring can be divided into three categories: General project-based cross-border cooperation, land monitoring related cross-border coordination, and sector-based cross-border cooperation.

General project-based cross-border cooperation

This category includes building cross-border Spatial Data Infrastructures (SDIs). The INSPIRE programme

7 INTERREG IVC provides funding through the European Regional Development Fund (ERDF) for interregional cooperation across Europe under the European Community's territorial co-operation objective. The 2007-2013 programme follows the INTERREG IIIC programme which ran from 2002-2006.

Figure 2. Areas in Europe where cross-border cooperation takes place. Source: AEBR, http://www.aebr.eu/en/members/map_of_members.php

and the public sector information directives trigger the construction of SDIs, not only at national and regional levels but also on cross-border scale.

Example: *The OTALEX project started in 1997 with an objective to monitor and analyse territorial and environmental changes as well as pressures on both sides of the border in two sparsely populated regions in Portugal (Alentejo) and Spain (Extremadura). The endeavour resulted in operative multi-language cross-border SDI and associated geoportal. National, regional and local level authorities on both sides of the border have cooperated to reach the common goal. The project was financed, at first,* *by the INTERREG III (ERDF) programme and the Operational Cooperation Programme Spain Portugal (POCTEP). The sustainability of OTALEX and future maintenance of the geoportal are part of the commitment undertaken by the partners, the Junta da Extremadura in Spain and the Comunidade Intermunicipal do Alentejo Central (CIMAC) in Portugal.*

Land monitoring related cross-border coordination

The pan-European CLC programme is the main harmonisation and coordination effort in the field of land monitoring in Europe. CORINE was initiated in order to collect information relating to the environment.

Example: *CLC is a centralised, remote sensing based, land cover mapping effort that has resulted in the CLC1990, CLC2000, CLC2006 land cover and datasets pertaining to the respective land cover change. CORINE was integrated in the work programme of the European Environment Agency (EEA) since 1994. The centralised approach to land cover monitoring production has gradually enhanced the increasing involvement of the member states. In CLC2012, the fourth CLC inventory, 39 European countries have participated with common specifications, despite a large variety of decentralised production methods. Cross-border cooperation and harmonisation related to land monitoring have improved thanks to discussions regarding the interpretation of the CLC nomenclature and the technical guidelines during the production of CLC.*

Sector-based cross-border cooperation

Harmonisation of spatial information between European Economic Area member states contributes to decentralised approach in European land monitoring, since harmonised data can be re-used in land monitoring. Harmonisation of datasets between neighbouring countries is required by both the INSPIRE Directive and the Water Framework Directive. Examples of sector-based cross-border harmonisation and coordination can be seen in the work done by mapping agencies, the water and forest sector, regional authorities, and other relevant parties.

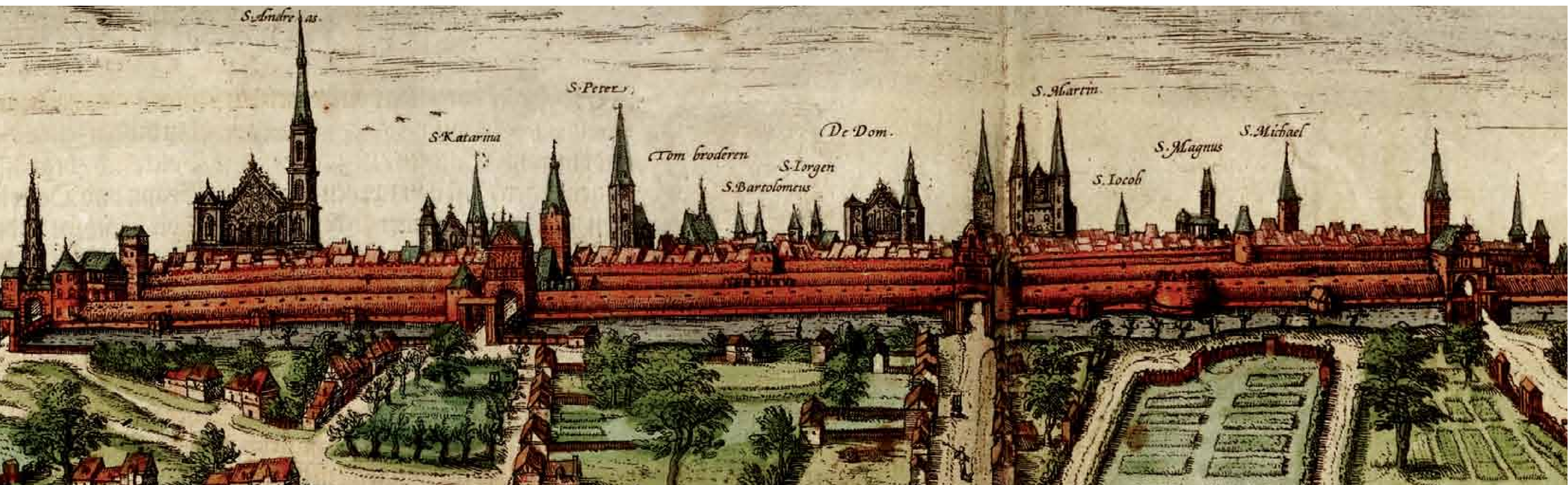
Example: *Cooperation between mapping agencies that are members of EuroGeographics has produced harmonised pan-European datasets collecting data of standardised characteristics. Presently, these agencies cooperate in a project pertaining to the State Boundaries of Europe (SBE), where the aim is to produce multi-purpose harmonised state boundary datasets at multiple scales. The harmonised products are produced on a voluntary basis, and currently the mapping agencies use their regular resources for updating existing pan-European datasets, each coordinated by a single partner, e.g., IGN France is responsible for the EuroGlobalMap since the beginning of 2011. EuroGeographics takes care of data sharing and licensing. This represents thematic cooperation between different countries, resulting in pan-European harmonised cartographic datasets ensuing from long-term planning based on legal agreement coordinated by EuroGeographic and supported by resources committed to that purpose.*

Bottom-up (decentralised) cooperation within European countries

Bottom-up cooperation includes federal-like bottom-up cooperative initiatives and national thematic cooperation. In practice, often both types of cooperation play together in the same scenario. There are three main types of bottom-up/decentralised cooperation in Europe: novel sectorial (horizontal) cooperation, agency-based sectorial (horizontal) cooperation, and federal-like cooperation.

Novel sectorial (horizontal) cooperation

Exercised between national central institutions, where several national central administrations enter a common agreement pertaining to technical specifications,



standards, guidelines, calendar, etc. They also collaborate in funding aimed at the production of national land cover (monitoring) inventory.

Example: *Finland boasts close cooperation between sectorial research and mapping institutions that are legally mandated to collect and maintain data and which have participated in national land use and land cover mapping activities. Among these institutions are Finnish Environment Institute – producing environmental thematic data; Finnish Forest Research Institute – producing National Forest Inventory data (NFI); National Land Survey – producing topographic map data; Agency for rural affairs – producing data on agricultural lands; Population Register Centre – producing building and dwelling data.*

Agency-based sectorial (horizontal) cooperation

Found between national central institutions and decentralised production systems run by regional or local administrations, where there is a national or central administration that provides technical specifications, standards, guidelines, calendar, etc. In some cases, the agencies would also provide funding for the production of certain national land cover (monitoring) inventories. Downstream, there are regional or local production teams that produce data according to these technical specifications in the given time frame.

Example*: Norway provides a set of fairly detailed databases produced by central and local administrations, based on an established set of technical guidelines, standards, etc., along with fixed production calendars and funding schemas. More generalised land cover maps (1:50,000 and 1:250,000 as well as CLC2000) are later produced by bottom-up aggregation and generalisation of data merged together from these databases.*

Federal-like cooperation

Established in countries featuring federal-like organisations, where successful bottom-up co-operation usually requires previous agreements between national and federal administrations and entities that would include technical specifications, standards, guidelines, calendar, funding, quality control procedures, etc. Such endeavours are normally led by a central administration acting as project leader. Once these are established, the local or federal administration entities produce the data.

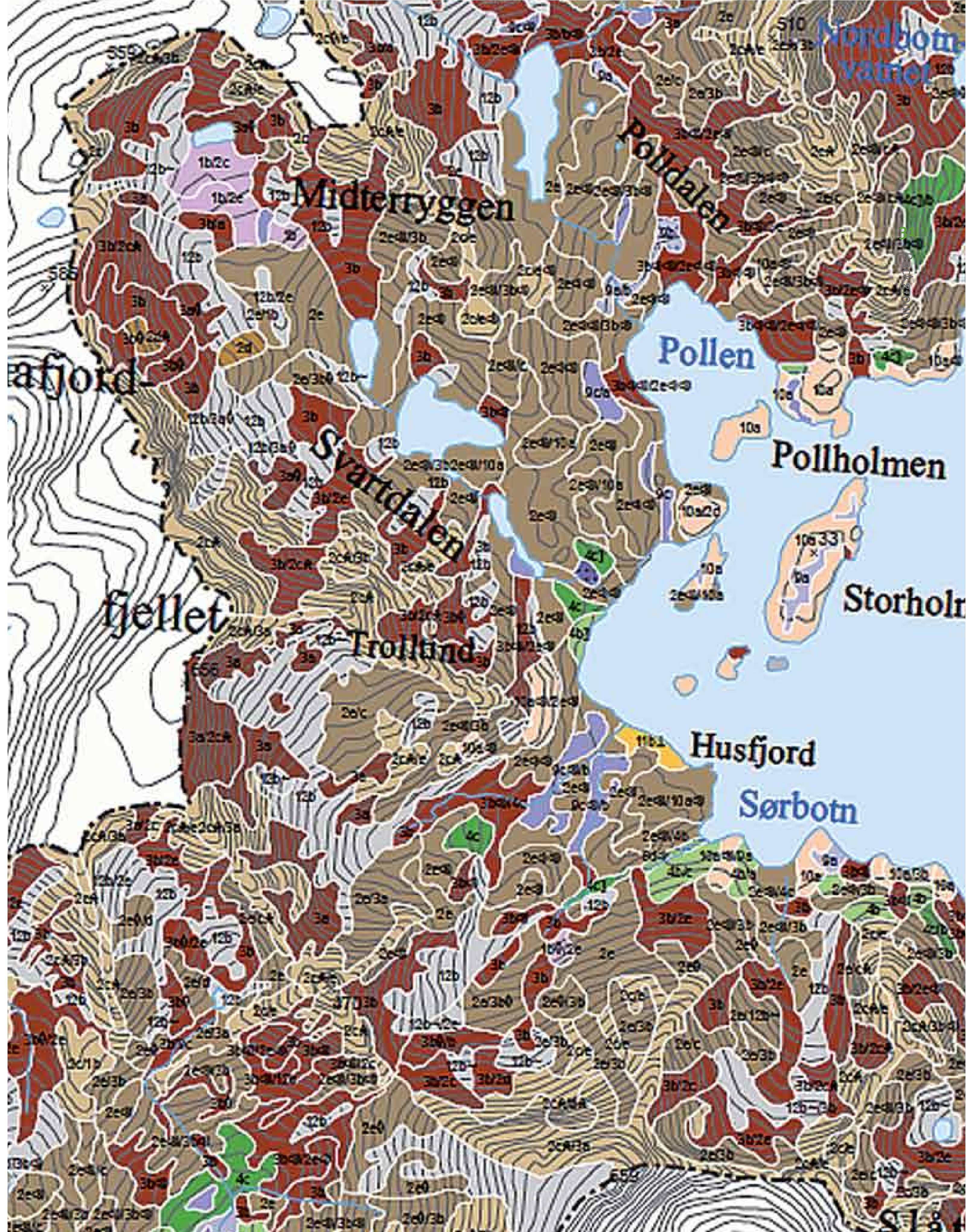
Examples: *The German ATKIS Basis-DLM (Digital Landscape Model topographic reference dataset) with a scale of 1:25,000 is used as basic input data for producing the DLM-DE (employing a CLC-compatible nomenclature) by remote sensing methods. Similarly, the SIOSE project (Land Cover and Use Information System of Spain), integrates different data of regional and national administrations, produced at national 1:25,000 scale. DLM-DE and SIOSE datasets are later used to produce the German and Spanish CLC for Europe, respectively (scale 1:100,000) by semi-automated generalization steps.*

Conclusions

Different European sectors are already implementing harmonised land monitoring practices in both cross-border and bottom-up cooperation. Notwithstanding, only a few of these have been sustainable and successful over time.

Essential elements common to successful cross-border and bottom-up cooperation are:

- Instigated by formal decision or reporting obligation at the national or European level;
- Led and coordinated by a permanent organisation or network that has clear responsibility in the subject of the cooperation;
- An organisational definition of responsibilities between partners;
- Based on sustainable long-term funding.



Challenges

Considering Best Practices in Europe

Both regional and national examples of land monitoring from across Europe show how stakeholders can benefit from the added value that best practices demonstrate. Such cases illustrate the potential improvement of the alignment and coherence of European land monitoring activities between different levels of aggregation, namely, regional, national and pan-European. Moreover, they point at the potential to integrate data throughout Europe. The kernel of the search of best practices comprises issues of strategic, technical, operational, and empirical nature.

Key messages

- Synergy is required between sectorial land monitoring to increase efficiency and mutual benefits for coordinated national land monitoring
- Implementation of modern data models (EAGLE) enables a clear differentiation between land cover and land use
- The emerging practise of three-dimensional data integrating object-height information should be further encouraged
- Inclusion of crowd-sourced information (e.g., OSM) increases timeliness, reliability and acceptability

Strategic issues

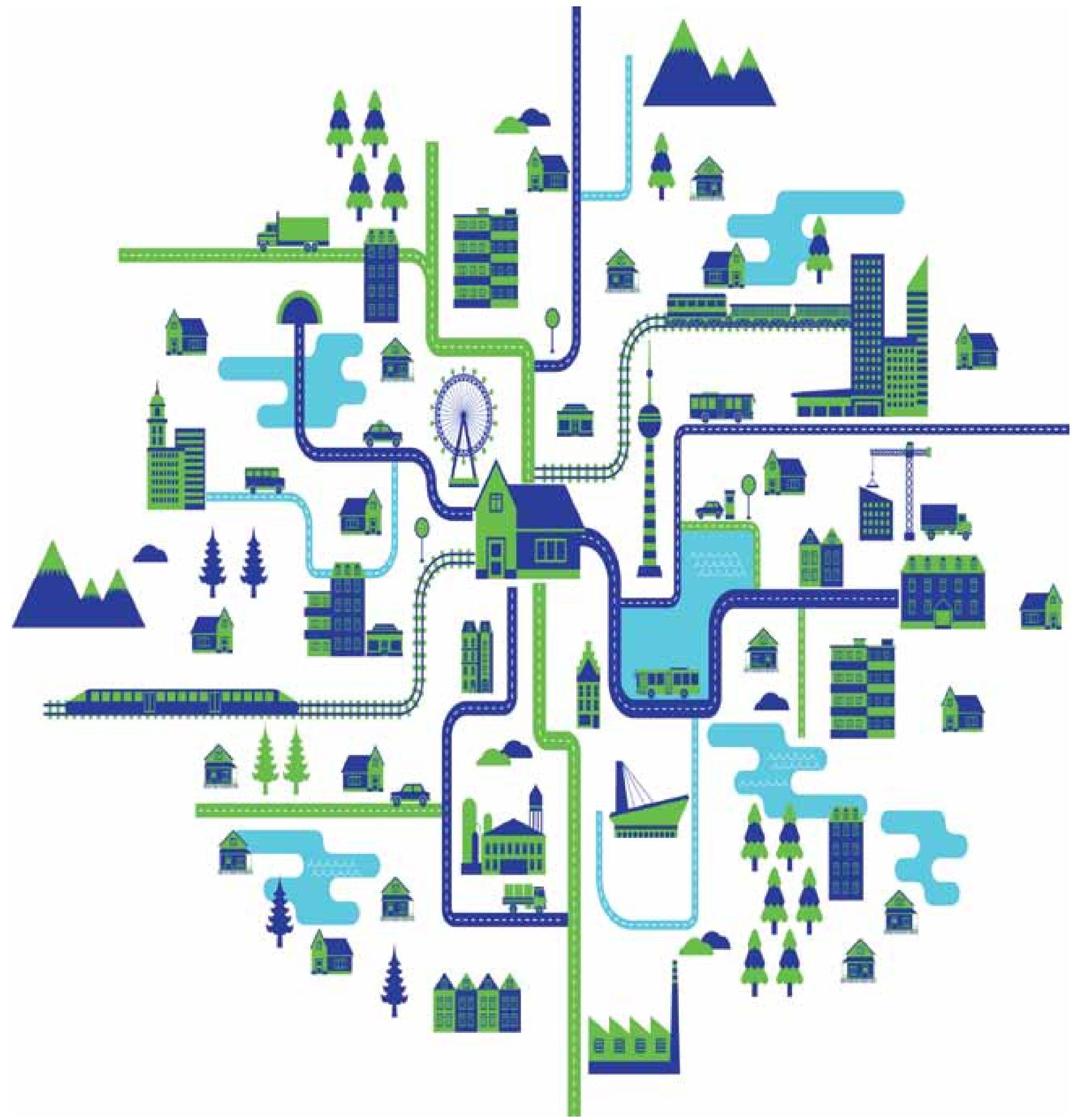
A primary strategic concern is funding. Financial capabilities that would support land monitoring differ widely from one country (or sector) to another. Often this is linked to legal constraints associated with the production, use, and dissemination of data. The need to increase efficiency of public investments creates opportunities for collaborated solutions. Such solutions are already in practice in Spain, Austria, and the Netherlands; they may have resulted from the needs of different organisations (sectorial or territorial), which combined both distinct requirements and a basis of similar needs (e.g., joint acquisition and usage of aerial images or orthophoto items).

Realities prevailing throughout Europe reveal a lack of a single legal, stringent set of obligations for land cover monitoring. A second strategic concern is the lack of synchronisation between the activities of statistical offices and mapping authorities. Sectorial monitoring programmes (e.g., forestry, agriculture, urban, traffic, natural areas), for example, are only at the early stages of implementation, reflecting immature systems.

Major bottlenecks in the path to harmonised data arise from legal constraints pertaining to the use of data in other fields. Finland and the Netherlands are good examples that demonstrate how data are made available for the land monitoring community by means of collaboration, for example, data extracted from the Land Parcel Identification System (LPIS) or topographic maps. In the Netherlands, all use related restrictions have been removed so that the land monitoring community can use topographic maps freely.

Technical issues

From a technical point of view, there are four elements that are of main interest: unique time stamp, standardisation, minimum mapping unit, and extension to three-dimensional information. Many applications require a unique time stamp, which cannot always be achieved due to practical constraints of remote sensing. Many countries, therefore, have adopted a monitoring system that observes a specific point in time in standardised time intervals (e.g., every three years). Countries still differ from one to another, however, in terms of absolute time stamps (e.g., 2005-2008 vs. 2006-2009).



To achieve interoperability between datasets, the Food and Agriculture Organisation of the United Nations (FAO) has developed the Land Cover Classification

System (LCCS) which also provided the basis for the corresponding Land Cover Meta Language (LCML) standard established by ISO (International Organisation for Standardisation). Currently the EAGLE group is elaborating a data model that can be developed into an enhancement and adaptation of LCML to European needs. Its current objective is to describe single land monitoring features (polygons, grids, points) with atomic landscape elements and their characteristics. The main focus here is on semantically exact definitions and accurate differentiation of land cover from land use and other environmental characteristics. This work is also linked to the concept of varying scales in land monitoring, as it incorporates different levels of details that can be mapped while applying specific minimum mapping unit. Each identified land cover unit (LCU) on a specific level of scale can be a part of another LCU on a more aggregated scale.

Due to technical constraints land cover monitoring has thus far focused on two-dimensional spatial observations. New technical possibilities (e.g., digital surface generation from aerial images) and available datasets (e.g., from airborne laser scanning) allow for the extension of land monitoring into three-dimensional datasets, including the height of objects (e.g., LISA – Land Information System Austria).

Operational issues

The availability of data (or lack thereof) is a crucial operational point in land monitoring, tightly associated with the use of available datasets. Which of these factors (availability or usage) plays a stronger role is yet to be established. Public participation is rather low therefore limiting public demand for access to data as part of public participation in issues related to land use. Such a poor level of involvement might be changed with the development of the Open Street Map (OSM) initiative. OSM is an example showing how informal standards are accepted and adapted by different communities, growing to be more helpful than official standards. Imitating this effect, the open government data (OGD) initiative currently increases the availability of public data without having to comply with formal binding standards (e.g., INSPIRE data specifications). Nevertheless, without the official processes of standardisation and interoperability efforts (such as INSPIRE), this OGD initiative would have been unable to gather such momentum as it actually has.

Coordination issues

National coordination is a crucial factor for implementing a land monitoring system. From the experiences in Spain and Norway it is quite clear that the users, producers and contributors of and to land monitoring systems have to be integrated at a very early stage in the process.

An important issue for national land monitoring systems is the coordinated acquisition of basic remote sensing input data. Aerial image flight campaigns are carried out at regular intervals (1-3-5 years) in many countries. Some countries also have programmes for satellite image data acquisition. Strategic long term planning of remote sensing data acquisition and securing an operational budget for this purpose is the key to sustainable land monitoring.

In terms of efficiency, the monitoring needs within a country have to be analysed carefully. Detailed monitoring is expensive and the accuracy may be adapted in certain areas or repetition cycles may be enlarged for certain areas or classes. The value of land (monetary or biological) can be used to select appropriate level of details.

Although probably too coarse to be used directly in detailed national monitoring, the European Copernicus products may still contribute to the efficiency of national monitoring systems if top-down and bottom-up approaches are combined. A proposal in this respect is to use European change data to direct the attention of national analysts towards the areas where changes most likely are taking place. Again, the basic issue is coordination between the stakeholders.

Operational Commonalities, Gaps, and Differences

Among the most significant on-going inventories serving general land monitoring purposes for Europe as a whole are the activities of CLC, LUCAS, GMES, Copernicus High Resolution Layers (HRLs), and to a certain extent the LPIS. These are supplemented and supported by various national land monitoring inventories.

The CLC inventory, with its 39-country coverage, 25-year history, and fourth update cycle in progress, can be considered as the operational quasi-standard for general purpose land monitoring in Europe. The inventory was created by the European Environment Agency in a situation where national land monitoring activities were rare and digital land monitoring data was almost absent at the national level. During the following quarter of a century, national land monitoring activities have evolved in many countries and several European bodies have also involved themselves in land monitoring activities. The result is a multitude of approaches, methods, and nomenclatures reflecting the wide diversity in the aims and scopes of the systems.

Key messages

- Gaps and variance across European land monitoring practices offer intriguing challenges as well as interesting opportunities
- Combined approaches will enhance the production of joint European land monitoring products
- Uniform pan-European data can be supported by diversity and well designed and organised work albeit differentially achieved will lead to good results

Commonalities and differences in methodology

In terms of general-purpose land monitoring, European countries can be divided into three major groups. Firstly, there are those countries where CLC is the sole or major land monitoring activity and other LULC data either do not exist or are insufficient for production of CLC in a bottom-up manner. The second group can be referred to as "innovative countries", where high spatial and thematic resolution is applied in national land monitoring using advanced technical solutions. Originally based on CLC, these techniques are now also used to derive more detailed data than CLC for use as input data in various national land cover monitoring activities.

Finally, there are those countries which employ the "Scandinavian model" where non-CLC-driven land monitoring exists along with large amounts of good quality thematic land monitoring data, and advanced aggregation and generalisation methods are used for CLC derivation.

The two commonly used approaches to derive general LULC information are computer-aided visual photointerpretation (CAPI) and semi-automated methods.

Visual photointerpretation has, in principle, a commonly shared methodology across Europe. An expert draws objects and gives attributes based on visual examination or comparison and evaluation of EO data, in-situ data and local knowledge. In CLC2006, 33 out of 38 participating countries applied this method.

Figure 3. Heidelberg, Germany – European land cover dataset (left side, CLC2006 © EEA) compared with the more detailed national land cover dataset (right side, DLM-DE2009 © GeoBasis-DE / BKG 2013)

Differences in CAPI results stem from four main sources:

- Software used, whether standard or custom-made;
- In-situ data availability according to monitoring activites applied in the member states;
- Human factors, e.g., differences in training, background, experience, and understanding;
- Inconsistencies, gaps, and insufficient descriptions in CLC nomenclature.

Homogeneity of CLC across Europe is ensured via centralised control of the national products.

Semi-automated methods for CLC production are unique to each country as they depend on available data and continuously change over time as new technologies and new input datasets become available. Semi-automated methods were initially applied in Finland, Iceland, Norway, Sweden, Switzerland, and the UK and later also Germany (Figure 3), Ireland, and Spain. The UK, which does not have a corresponding national dataset for the time period of CLC2012, is now reverting to the CAPI approach. Practices common to most semi-automated methods for status layer derivation are:

- Classification of EO data into land cover information;
- Geographic Information System (GIS) integration of LULC data from national databases (data merging);
- Generalisation to aggregate to larger spatial resolution than national land monitoring data;
- Production of individual thematic layers for each CLC class and subsequent merging of the layers according to a priority list.

In change mapping, such practices include:

- Differentiation of existing databases;
- Using database information to identify areas of potential changes.

Commonalities and differences in data sources

Data used to support land monitoring at the national or European levels also show diversity. Most actors rely primarily on satellite images from joint acquisition organised at a European level (mostly for CLC). This is supplemented by EO data available at national mapping agencies, freely available archives and Google Earth.

Orthophotos, usually derived from joint acquisition organised at national level, are mostly available in countries where LPIS is an obligation, but are typically fee based and only occasionally can they be accessed.

The use of thematic data to support land monitoring is common in most countries. The most widely used data are agricultural, followed by topographic and forestry data. Mining or transportation data are rarely used, probably because these areas are not that relevant to land monitoring on a pan-European scale (geometry, attribute completion, etc.). Topographic maps (1:25.000-1:50.000) are available in most countries, but not always in digital form or freely. In addition, maps are frequently outdated.

Commonalities and differences in data model and nomenclature

The typical land cover data model currently used is that applied by CLC. The geometry consists of polygons representing tracts of land with homogenous land cover, which is described by assigning classes from a hierarchical nomenclature. There is, however, a wide variety of nomenclatures: out of the national land monitoring nomenclatures examined, eight are CLC-compatible, two are object-oriented, eleven separate LU from LC, one is FAO-LCCS-based, and six are other non-CLC-compliant types.

Gaps forming major obstacles of a harmonised European land monitoring

National data (orthophoto, topographic map, forest map, LPIS, forest map, national LULC inventory) may be missing, inaccessible or not up to date. Major obstacles of use are: confidentiality, high price, no infrastructure for large data volumes, and currency. No single data model or nomenclature is fulfilling both European and national needs. Timing of inventories varies from continuous updates to 1-10-year update cycles.

Operational conclusions and recommendations

Summarizing the above, Table 1 delineates both operational challenges and possible solutions.

Table 1. Operational challenges and possible solutions

Challenge	Solution
Overcoming differences and filling gaps in data and approaches in national systems	Harmonisation and coordination at the national level
Differences in mapping / database derivation methods are a minor obstacle	Collection of best practices of aggregation and generalisation could enhance harmonisation
Availability of in-situ data is dependent on collecting agency. These data are generally much more easily available for national institutions than for European institutions and their subcontractors	A bottom-up approach should be applied, as opposed to fully top-down initiatives
Resolving incompatibility of nomenclatures and databases	Progress can be made with a descriptive object-oriented approach, such as the EAGLE data model
Inadequate or absent data synchronisation	Adaptation to CLC/HRL update cycles provided centrally or – in line with Shared Environmental Information System (SEIS) principles, continuously collected national datasets could be synchronised with "harvest" timing of European databases
Disagreement regarding the optimal geometric object	To ensure stability, it should be maintained independently from mapping projects. Available options: raster (grid approach), administrative, LPIS blocks, CLC polygons
Lack of compliance between previous European-level CLC inventories and new bottom-up-created CLC databases	Cross-national and pan-European alignment of time frames would result in gradual amendment of this incompatibility

Common Needs and Tasks

When attempting to delineate the issues pertaining to the harmonisation of land monitoring, it would be highly important to identify common land monitoring activities and practices, such as data models, image acquisition, image pre- and post-processing workflows, data fusion, products delivery, available human resources and technical infrastructure. To establish a sufficient body of knowledge in this regard, relevant information was collected – and analysed – pertaining to these issues. To this end, a focused questionnaire was designed so as to enable the collating of related information and knowledge.

The questions addressed issues related to the common activities and practices but also to areas of potential synergies. The questionnaire was dispatched among HELM project participants, as well as to European stakeholders associated to the project. Altogether 34 responses were received, covering a wide range of the relevant institutions throughout Europe.

The need for land monitoring activities (LMAs) is usually driven by national requirements related to the environment. The typical participant in the survey would be, for example, a public institution acting mainly as a user, whose dominant activity would be mapping or data analysis.

Respondents were institutions of public, academic, research or private nature. As it were, none of the survey participants represents a non-governmental institution, an important user of land monitoring outcomes. Figure 4 shows the division of responding organisations according to type.

A point of interest is the participants' roles in land monitoring processes, which varied despite their common public nature. Some institutions were identified as sponsors, steering bodies or managers while most have been users of land monitoring products or data contributors for LMAs. In many cases, the responding institutions have indicated that they had served in more than one capacity, at times simultaneously, e.g., manager, user, data contributor, and producer. The last two (contributor and producer) emerged as the most frequent combination.

Commonalities between organisations

The HELM questionnaire showed that many European countries produce land cover data at neither national, regional or local level. The responses thus demonstrate LMA in these countries is based on CLC, or closely connected to CLC in terms of data acquisition, pre-processing, processing, quality assessment (QA), quality control (QC), dissemination and creation of metadata.

These findings infer that the most used in-situ data supporting LMAs at national or European level are agricultural data, followed by topographic and forestry data. Resource exploration and mining or transportation data seem to be very rare, probably because these fields are not that relevant to LMA on a European scale (geometry, attribute completion, etc.), while most of the countries do not produce LC on national level.

The data mostly produced are multipurpose land cover at national, regional, and local levels. This is followed by environmentally related data, dealing with nature conservation and biodiversity. The division of satellite and aerial image data supporting LMA by area of interest is demonstrated in Figure 5.

In terms of satellite images, the majority of the respondents supported joint acquisition organised at multi-national (e.g., European) level, as is already the case with CLC. Acquisition of aerial images, on the other hand, is mainly organised at the national level. This specific activity should thus remain at the national level although cross-border cooperation is necessary. Use of in-situ data to support LMAs appears to be common as well. The typical harmonised land cover data model currently used by organisations for in-situ database merging is based on the CLC nomenclature.

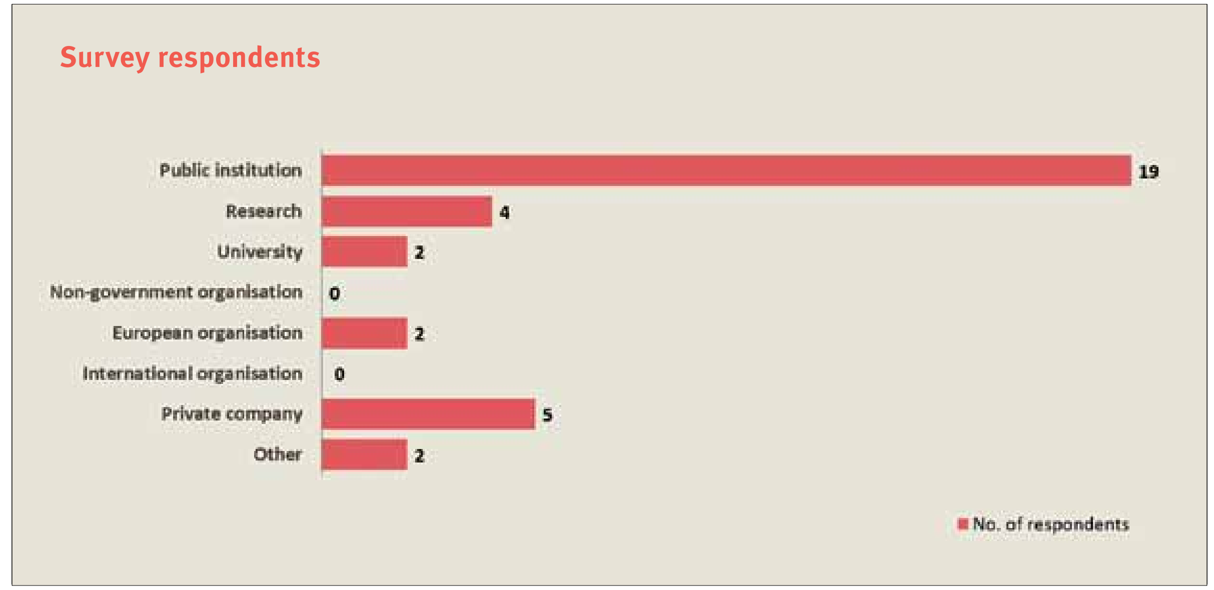


Figure 4. Institutions responding to HELM's common needs and tasks survey

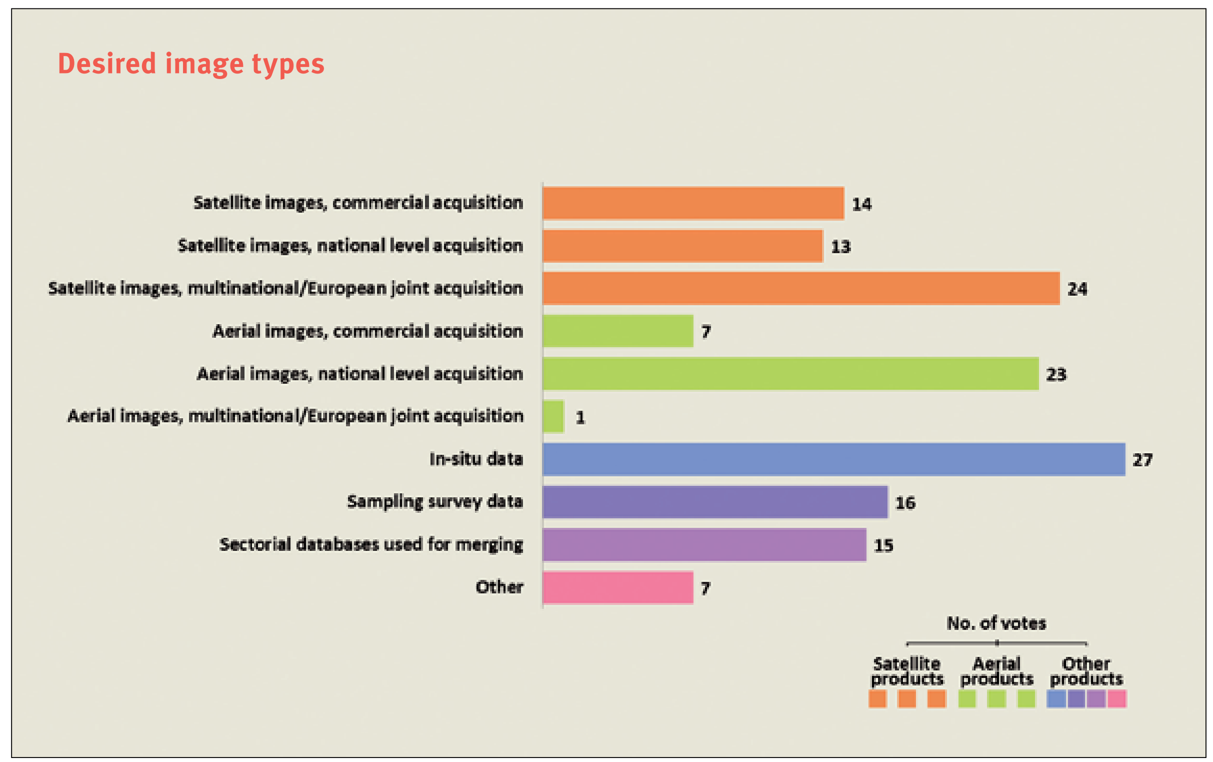


Figure 5. The distribution of image data types used to support LMA

Several of the organisations surveyed expressed a need for experts to help them handle LMAs. The need of support in IT and data modelling is particularly significant for the development of bottom-up land cover monitoring approach. A growing need is developing for positions such as those of image analysts, GIS specialists, thematic experts, quality and validation experts, LMA data assessment experts, scenario modellers, and policy document creators. It would thus benefit land monitoring efforts if these are established in the future.

Survey participants also indicated the need to strengthen their capabilities in the areas of hardware and software, GIS software supply, metadata, and dissemination tools (map server or web portal). The problem is not the availability of useful software and hardware but rather the lack of finances for purchasing – or otherwise employing – such software and hardware and also for engaging the required experts, as noted above. Improvements are also necessary when aiming to publish INSPIRE compliant LC data and services.

Combining tasks and potential synergies

In-situ data are considered as most unique and non-transferable, that is, they are most sensitive in terms of cooperation. Most transferable is Copernicus services dataset acquisition, indicating that the best potential for synergy lies in acquisition of Copernicus services datasets and satellite images.

Because LMA in several countries is limited to CLC, respondents have stressed such a reality where activities that can be combined are already carried out as part of CLC, such as satellite image acquisition, pre- and post-processing, creation of image mosaic, data model specification, QC/QA, metadata specification and creation tools, cross-border data harmonisation, etc. Also, based on the need for experts as described above, it seems clear that most organisations engaged in LMAs cannot carry these activities out if not taken collectively.

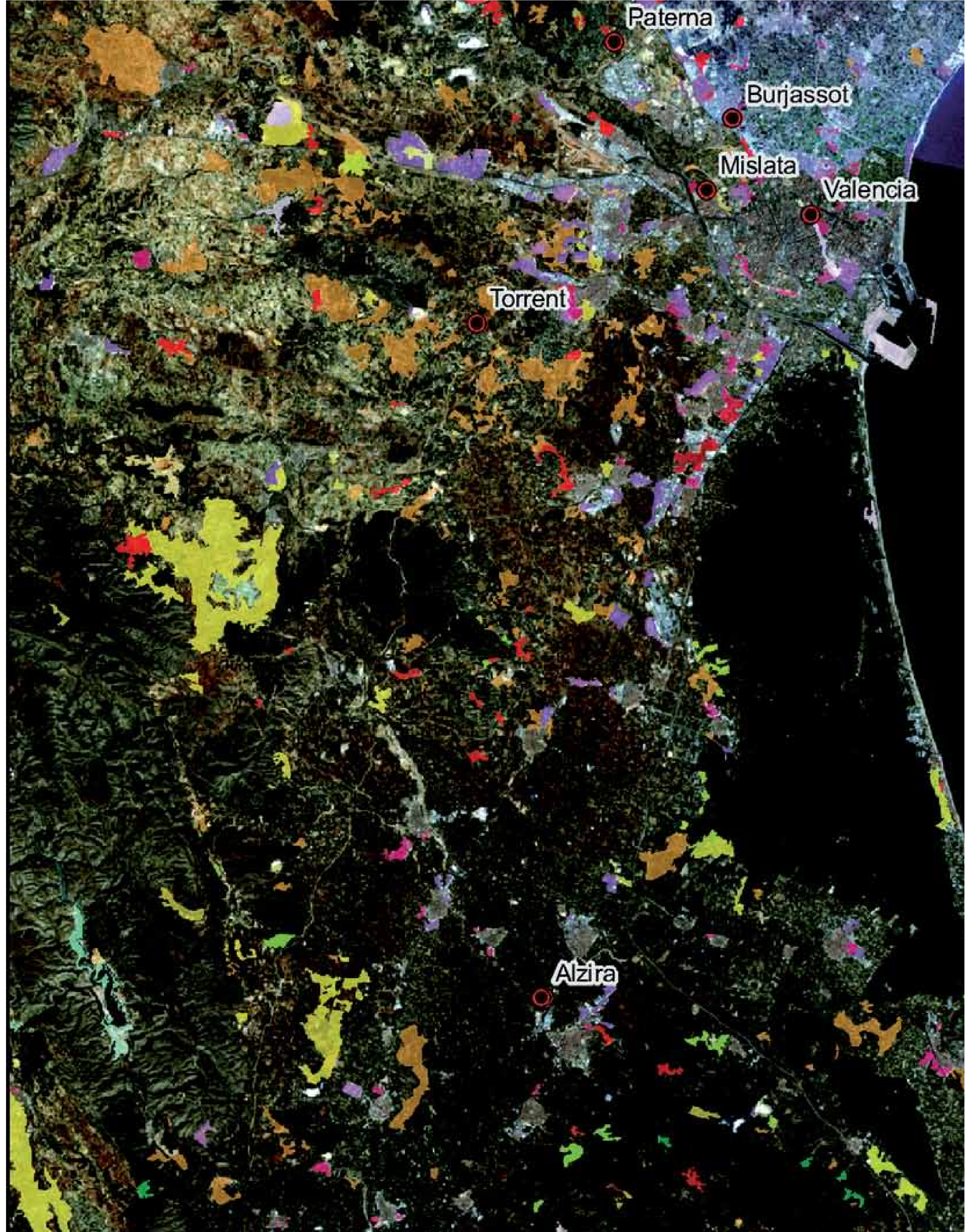
It is interesting to consider the responses obtained in the area termed “potential for synergies at European level”. It appears that there is a rather high demand for sharing knowledge in all topics related to data analysis, including analytical methodology, instruments, indicators, scenario modelling and reporting approaches.

Survey participants were asked to suggest ”the best three” candidates with the highest potential for synergies, so as to examine their ideas for land monitoring activities and potential synergies. Respondents have expressed potential for synergies in different ways and have seen cooperation in different areas. Based on the survey, areas for cooperation can be divided into the following four rudimentary categories: synergies in the acquisition and processing of data, harmonisation of approaches, institutional support and the use of supportive initiatives (INSPIRE, EIONET, EAGLE and Copernicus user forum, followed by the grid approach). Most important amongst these has turned out to be harmonisation of approaches, which was followed by synergies in the acquisition and processing of data. The role of various institutions and initiatives has been seen as less important.

Synergy-related conclusions and recommendations

It seems that current LMAs point at considerable potential for further development of harmonisation in LMA on both national and European levels. Many opportunities can develop through the availability of harmonised Copernicus data and services. This will enable the construction of common approaches and methodologies to further support LMAs.

Stakeholders and decision-makers should consider the needs defined by the land monitoring community along with outcomes from user driven projects such as HELM so as to better support the establishment of Copernicus services and their content from the viewpoint of harmonised land monitoring.



Foresight

Common Strategic Views

The prerequisite for unified and coherent efforts of the European countries in the area of land monitoring is the widely held conviction that close collaboration is beneficial for all parties involved. Therefore, the envisaged land monitoring system must be based on common interests of the participants so as to enable them to jointly take advantage of mutual benefits. At the same time, many European countries have their own history of land monitoring activities and their land surfaces are characterised by specific bio-geographical conditions that differ from those characterising other countries. Therefore, the common strategy articulated by HELM participants does not necessarily call for a "one and only" single opinion in every applicable aspect, but rather, it implies that all partners respect, accept, and value the diversity of views among the group.

Decentralised or centralised?

From a strategic perspective, two approaches may be applied. Data can be gathered bottom-up, that is, decentralised by the member states or top-down, that is, centralised via tenders published by pertinent European institutions. Each of these approaches has advantages and limitations (Table 2). CORINE is the first operational pan-European dataset of land surface cover and use. This programme has paved the way for Europe-wide collaboration in land monitoring. In the meantime, there is a very valuable time series of several updates which allows for the detection of major changes in the land surface. The datasets were produced by the member states under the coordination of the EEA. The current Copernicus HRLs are an example of centrally produced pan-European land use and cover data.

Key messages

- Land monitoring is optimal at local, regional, national levels combined with centralised services
- A coordinating land monitoring agency would help to overcome local administrative and technical issues
- A shared strategy should recognise the variety of local interests among group members rather than dictate an all-inclusive, single path for all
- Centralised data promotes standardisation in pan-European land monitoring

Table 2. Advantages and limitations of centralised and decentralised land monitoring data and production

Criterion	Centralised production		Decentralised production	
	Advantages	Limitations	Advantages	Limitations
Knowledge & datasets	European stakeholders can act independently	Resources are wasted due to parallel production of European and national datasets	Knowledge of local circumstances leads to high data quality	Absence or partial comparability of national datasets
Links between datasets	Thematically arranged production lots are a priori uniform	National authorities often already own higher quality data	Link between national and European datasets is assured	Harmonisation effort needed regarding semantic adjustments
Data production	Readily achieved overview on continental level	National data not fully compatible to separately produced European data	Data are produced only once to quality required at base level	Quality of base data used varies among different member states
Data location & interpretation	Easily organised (via tenders) and quickly completed production	Higher chances of misinterpretations owing to insufficient local knowledge	Data are kept close to their source	Incompatible generalisation and downscaling approaches
Data direction & frequency	Input data can be purchased at a cost-effective rate	Time pressure restricts application of detailed expert knowledge	Efficiency as European datasets are derived from national ones	Unsynchronised timing and frequencies of data gathering

The HELM vision

The comparison of decentralised and centralised land monitoring in Europe suggests a combined approach. HELM proposes the following future developments:

- Member states implement professional, operational, and authoritative national land monitoring systems;
- These systems should be aligned in that their outputs are compatible with one another and also adhere to the European stipulations;
- Through upward aggregation and generalisation, European products should be produced directly from the national products;
- Products should be designed to fulfil the needs of both European user organisations as well as users in the member states;
- Decentralised production should be centrally supported in that base data required by the member states will be provided through a common source;
- An integrated European land monitoring system should combine high data quality and economically efficient work.

Realising such a harmonised European land monitoring system does not mean starting from scratch. Existing experiences in cross-border collaboration can be utilised. Interestingly, collaborations between countries and also between regions within one country show several similarities, so that experiences may be exchanged between such cases.

As long as not all member states contribute to a multinational land monitoring system, gaps in the aggregated datasets must inevitably be filled by the central element of the system, for instance, through products such as the Copernicus HRLs produced only for these areas. HELM, thus, considers a gradual transition towards a completely coherent system.

Data policy

In accordance with data sharing principles of the Groups on Earth Observations (GEO), full benefits of EO data cannot be achieved without data sharing. The composite land monitoring system proposed by HELM requires broad access to both remote sensing and ancillary data in all participating countries – a condition yet to be established. As it were, data policies of several national data holders are at odds with the HELM concept, impeding free and open data exchange. Currently, certain datasets are available in some countries but not in others. Data sharing and aggregation is further complicated by ambiguous distribution of internal responsibilities for land monitoring in several member states. Establishing administrative conditions across Europe that are suitable for effective ongoing data exchange should thus be of high priority.

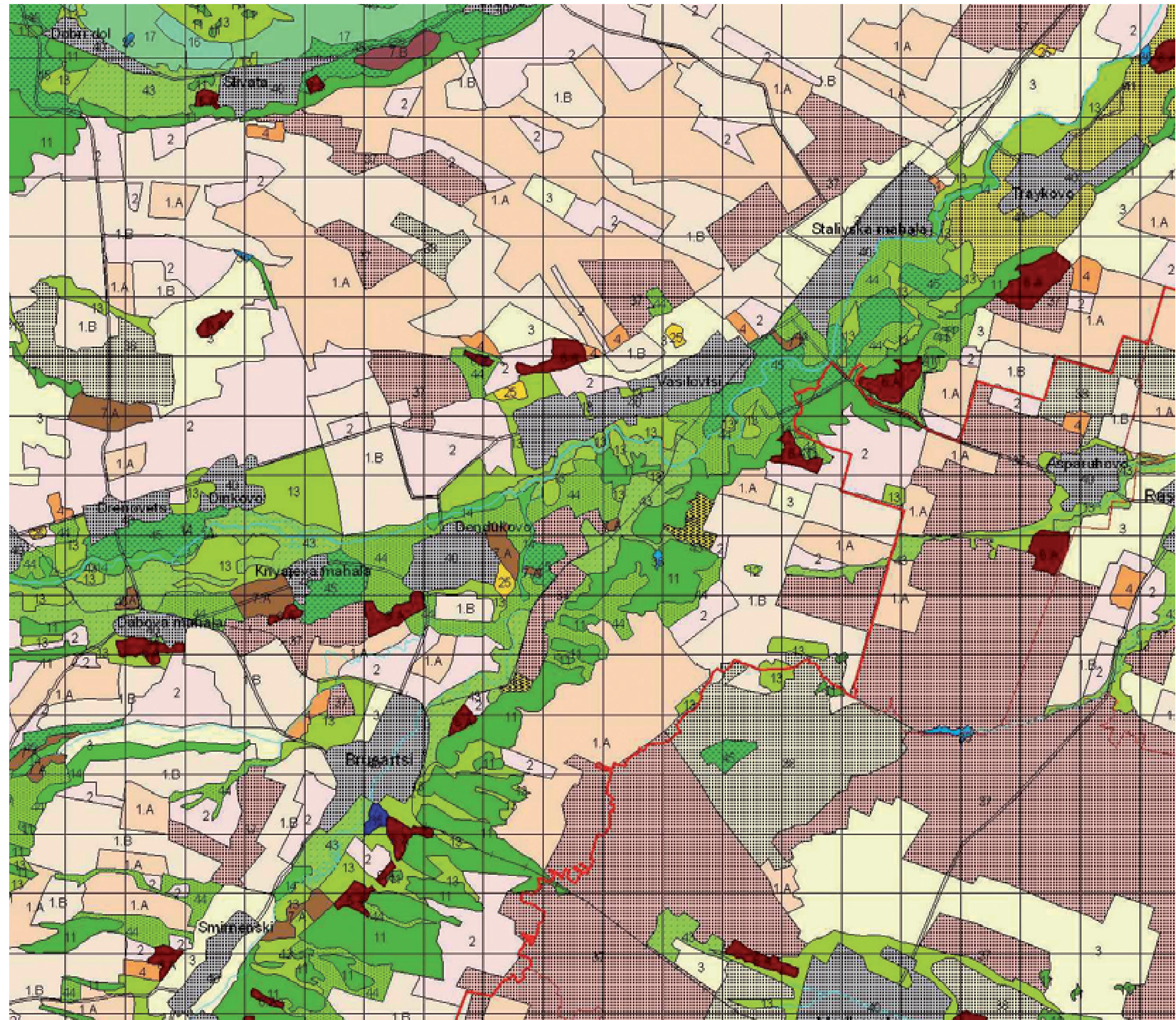
Besides legal and financial access conditions, the administrative efforts required by data users should also be kept as minimal as possible as they extensively influence the degree to which datasets can be employed in an operational manner. Datasets should always be accompanied by sets of sound metadata (in conjunction with requirements defined through INSPIRE) so as to ensure their suitability for the purpose.

Cost sharing

Cost sharing between European and national institutions is a means to enable the construction of the highest quality datasets in the most efficient way. In this economic model, primary activities such as practical land monitoring based on common criteria are financed at national level, and in return, the European level would finance base data, such as corrected imagery and simply derived products, like a basic change mapping. Ideally, all extraction of information and data production should take place on member state level, supported by local knowledge of landscape, so that subsequently, European stakeholders receive high quality aggregated data products matching bottom-up coherence and pan-European applicability.

Political framework

A well-functioning multilevel political framework should produce long-term mutual benefits for EU institutions and organisations in the member states. EU Institutions, especially the EEA and the pertinent EU Directorates General, should have a coordinating role in this framework. Likewise, this coordination should encompass a clear definition of the rights and duties of affected organisations in the member states, especially regarding data flows and validation. The design of a pan-European land monitoring system is in several regards a technical and scientific challenge, but it cannot be executed without a clear political decision. This decision should bring about a long-term programme that requires all participants to enter into coherent engagements. This programme should also establish the needed communication channels for the ongoing exchange of practices and the joint creation of commonly accepted solutions. A suitable political framework could be a thematic strategy or even a directive to the purpose, which makes land monitoring a formal and compulsory reporting requirement.



Centrally Provided Services

The HELM project, amongst others, has also focused on the investigation of operational commonalities, differences, and gaps in national monitoring systems and the subsequent identification of common needs, requirements, and tasks that ought to be tackled as combined endeavours.

The aim of these undertakings was to identify the characteristics of national land monitoring activities and to determine how these activities could best be reinforced and supported by new centrally provided Copernicus products and services, creating benefit to users at various administrative levels (from regional to European) and for a potentially broad range of applications.

Key messages

- Currently produced pan-European data support European wide policies but are limited in their usefulness at national level and below
- Centrally produced data should adhere to local and regional quality requirements especially in favour of countries devoid of land monitoring practices
- National users prefer less developed, low level products, including image data
- Validation, technical specifications, and processing chains are important to build trust in Copernicus products
- A user friendly Earth Observation image data service is in demand

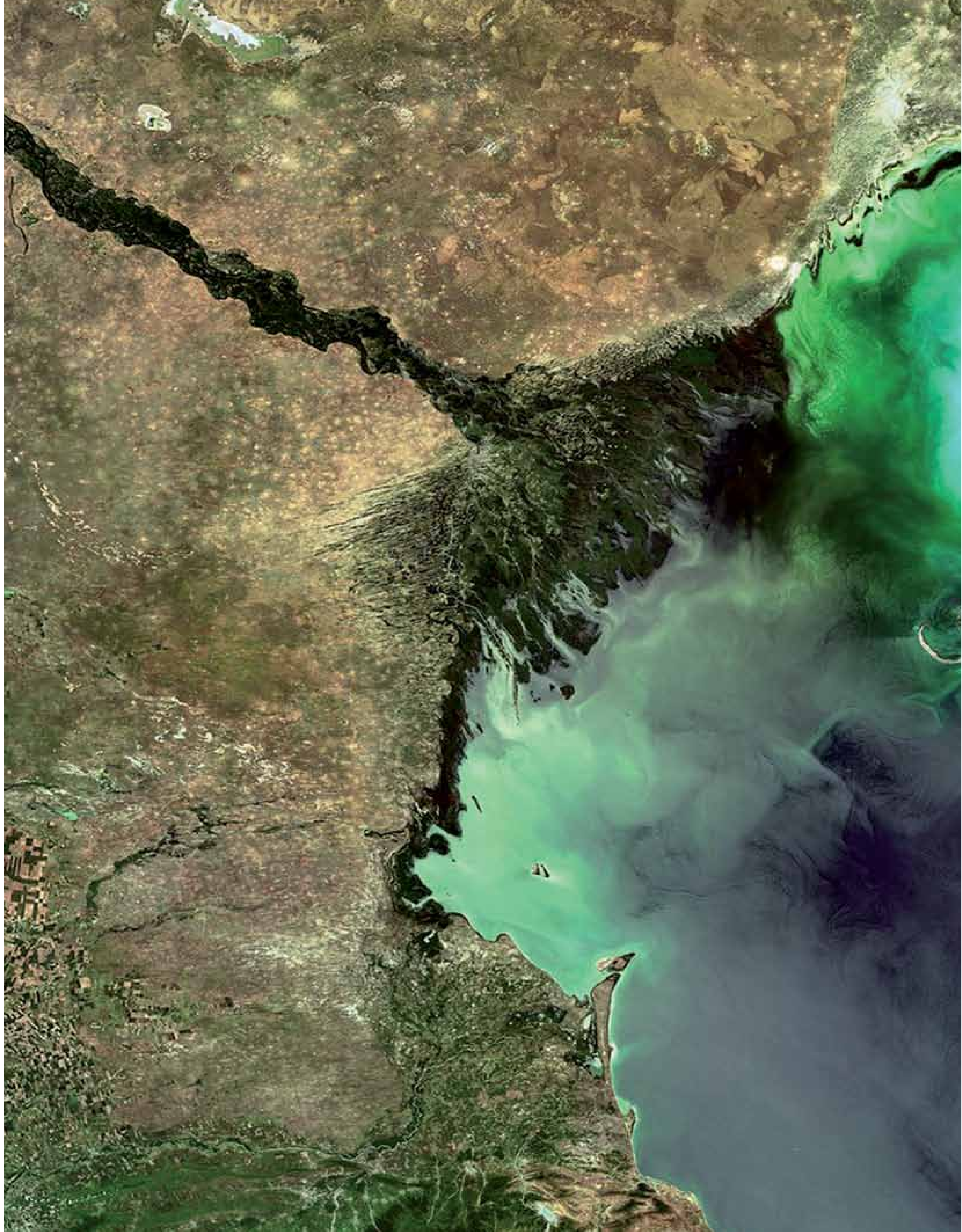
There is little doubt that the currently produced data and information – in the context of the Copernicus pan-European (e.g., GMES Initial Operations – GIO-HRLs) and local component (e.g., Urban Atlas and riparian zones) – are required to support European-wide policies and their needs for comparable information. Still, during the discussion country representatives expressed some difficulties and uncertainties when it comes to using such centrally produced information at the national or regional levels.

Major findings

Acknowledging the usefulness of centrally produced data in countries without national monitoring programmes and where CLC is still often the main source of land cover information, countries with their own national land monitoring data are often seeing three problems:

- The centrally produced data are spatially too coarse for national or regional applications;
- The level of quality required for European statistics is not likely to be sufficient for local and regional applications;
- Countries already hold (better) information which they would like to be able to integrate into the centrally produced data to improve the usefulness of data for their territory.

At the time of these discussions the final specifications of the GIO-HRLs were not fully defined and made available,



therefore several representatives expressed reservation regarding their applicability to national and regional uses. Consequently, the group decided to refrain from further discussions about additional HRLs until the current layers are better understood.

A second concern expressed by the participants arose from the lack of public knowledge about the specifications of the processes where HRLs are actually produced. In fact, for several users, a "knowledge box" with detailed technical specifications on the processing chain of the layers was considered to be more interesting than the actual GIO-HRLs. This is mainly because it would enable the user institutes to produce the layers based on common EO data in combination with national in-situ data.

Member state representatives have requested more transparent validation methods, which should be centrally defined but decentrally applied, i.e., countries would use their local knowledge to validate centrally produced information layers. Validation and better knowledge of the technical specifications and processing chains are considered important elements to build trust in the Copernicus products.

Finally, the EAGLE concept (both the data model and the matrix) has been acknowledged by participants as a possible way forward in terms of supporting bottom-up approaches in European land monitoring harmonisation and integration of HRLs. Therefore, it is recommended that future HRL development be aligned with the attributions suggested by the EAGLE concept.

Recommendations for centralised services

These considerations and the identification of the most beneficial synergies in European land monitoring systems have led to the formulation of the following recommendations for new Copernicus products:

- National users, especially those with sound data processing capacities would prefer less developed products, i.e., more low level, pre-processed and intermediate products which they can customise and finalise according to their own needs;
- Pre-processed and intermediate products of interest should include: pre-processed ortho-correction, calibration, cloud masking, intermediate – biophysical parameters, multi-temporal data (time series and phenological dynamics).
- In addition to these products, the highly desirable EO image data service should be developed. Such a service should provide frequent and sustainable updates with easy access to raw image data, different image pre-processing levels and quick-look functionalities. In fact, all available images should be stored in an online data archive, independent of any acquisition windows or similar constraints, where users are able to select suitable EO data based on their specific requirements.

Implementing these ideas would best be done via a "shopping centre" (see Figure 6) for centrally produced services. In this yet to be developed shopping centre users would be able to obtain products at any stage and level of the processing chain (from raw images to final products) for direct use or further processing.

In addition to new products, some enhancements for existing products have also been proposed:

- Improving the HRL concept so as to fulfil criteria of exclusiveness (no overlaps) and completeness (no thematic gaps) in line with the EAGLE concept;
- Enhancing CLC by semantic description of CLC classes, so as to help a translation to and from national nomenclatures and LULC information while also improving CLC nomenclature by removing gaps, overlaps, and inconsistencies;
- Enhancing the CLC concept in order to allow for attribution of CLC polygons (e.g., via HRLs) as a first step towards an object-oriented approach.

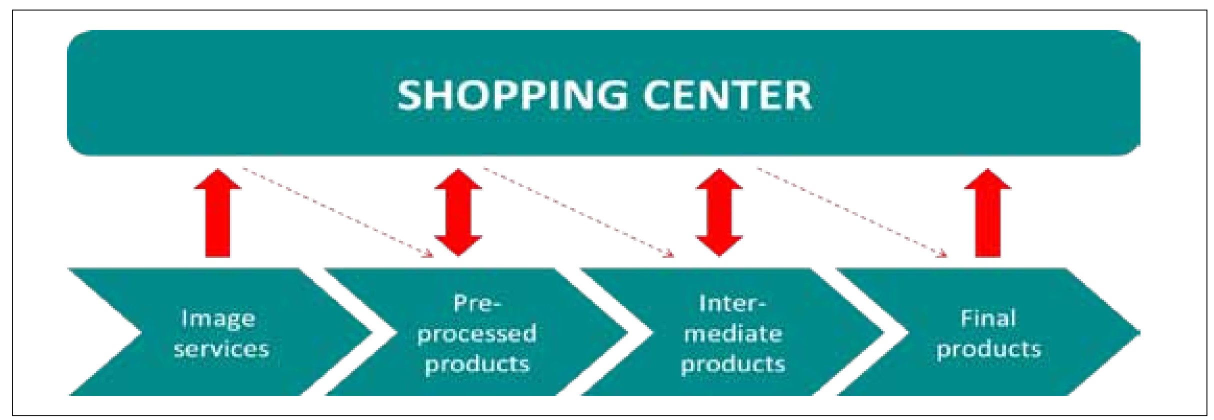


Figure 6. Shopping centre for central services and products

The EAGLE concept: A land monitoring data model

The diverse applications of LCLU data have led to the development of many classification systems. Most of these contain a mixture of land cover and land use information. Each application emphasises particular aspects of land cover and land use, related to specific requirements and purposes. Furthermore, data collection methods, scales, tailored-to-purpose definitions and lack of completeness hamper the data transfer from one application to another.

Given situation

The concept and nomenclature of CLC has established itself as the quasi-standard for LCLU mapping in Europe. After 25 years, the technical circumstances including quality of affordable satellite imagery, data storage capacities and methodologies, as well as thematic requirements and political reporting obligations have evolved and changed. Consequently, the need for a revision of the CLC concept has become evident. The most evident shortcomings of the CLC nomenclature are:

- Mixed land cover and land use information;
- Ambiguous description and semantic gaps or overlaps provoke inconsistencies in class definitions;
- Only selective incorporation of temporal aspects;
- Lack of thematic content details (e.g. differentiation of grasslands and wetlands, cultivation practices, parameterised information like imperviousness or crown cover density);
- Missing option for the attribution of spatial units;
- No flexibility to react to the appearance of new landscape phenomena (e.g. energy crop plantations, artificial snowmaking or habitat restoration);
- Inconsistent and unequal representation of landscape types from different bio-geographical regions.

Key messages

- The EAGLE matrix is a tool for analytic decomposition of class definitions and semantic translation between recent or future LC nomenclatures
- The EAGLE model is a conceptual basis for future harmonised European land monitoring and may be implemented as an object-oriented guideline for mapping and monitoring initiatives
- The EAGLE concept is not another classification system but a descriptive vehicle for harmonisation of LCLU information supporting both top-down and bottom-up approaches

Criteria collection

Facing existent and upcoming monitoring requirements, a list of criteria has been made in response to the identified CLC shortcomings.

From the conceptual point of view, the data model for a future European land monitoring system should:

- Be object-oriented and describe landscape by its elementary properties instead of classifying it;
- Separate land cover from land use information;
- Describe land cover in a mutually exclusive and comprehensive way;
- Be scale-independent;
- Allow semantic translation between classification systems;
- Be INSPIRE compliant;
- Support the bottom-up approach as well as top-down initiatives;
- Store parameterised data such as counts and numerical values;
- Be capable of handling spatial multi-scale dimensions and temporal aspects;
- Be flexible enough to allow the insertion of new elements in the model.

The EAGLE concept

The EAGLE data model considers and actively refers to these criteria. It clearly separates between land cover and land use information, is scale independent and also tackles the temporal aspects of transient or altering phenomena. Its structure is flexible enough to react on user needs arising from different fields of application and institutional levels. The EAGLE concept is technically represented as a UML (Unified Modelling Language) chart and a cross-table (referred to as the EAGLE matrix).

The identical contents of the UML chart and the matrix are divided into three blocks:

- Land cover components (LCC) such as sealed surfaces, woody vegetation, water bodies;
- Land use attributes (LUA) such as agriculture, forestry, residential, mining;
- Additional characteristics (CH) such as cultivation measures, biophysical parameters, ecosystem types, status, spatial patterns, temporal patterns.

The matrix and the data model have the same thematic content. The matrix contains all model elements (as table columns) in a hierarchically grouped order. The data model with its UML chart brings these model elements into relation with each other with their inherited properties. The compilation of matrix elements inside these three matrix blocks (LCC, LUA and CH) is based on existing specifications such as INSPIRE, CLC, LUCAS, ISO 19144-2 LCML, EUNIS and some national nomenclatures. As the matrix and model are still in the development phase they are living documents and therefore subject to changes.

Figure 7 shows the simplified structure of the object-oriented EAGLE data model, consisting of three main segments of Land Cover Components (LCC) distinguished by their (bio-) physical appearance: Abiotic (non-vegetated) artificial and natural surfaces, Biotic (vegetated) surfaces and Water surfaces. Each segment contains a number of LCCs hierarchically ordered in sub-branches. The LCCs are further described with additional landscape characteristics (CH) that express more specific details about their properties.

Following the structure of the UML model, one or several LCCs with their attached characteristics build a Land Cover Unit (LCU) that also can have its own specific characteristics. The LCU is completed by the additional information of LUA originating from the Hierarchical INSPIRE Land Use Classification System (HILUCS) and extended by EAGLE-specific sub-types. LCCs are mutually exclusive. Several LCCs can occur inside a LCU, but they cannot overlap. LUAs, however, can occur in an overlapping manner.

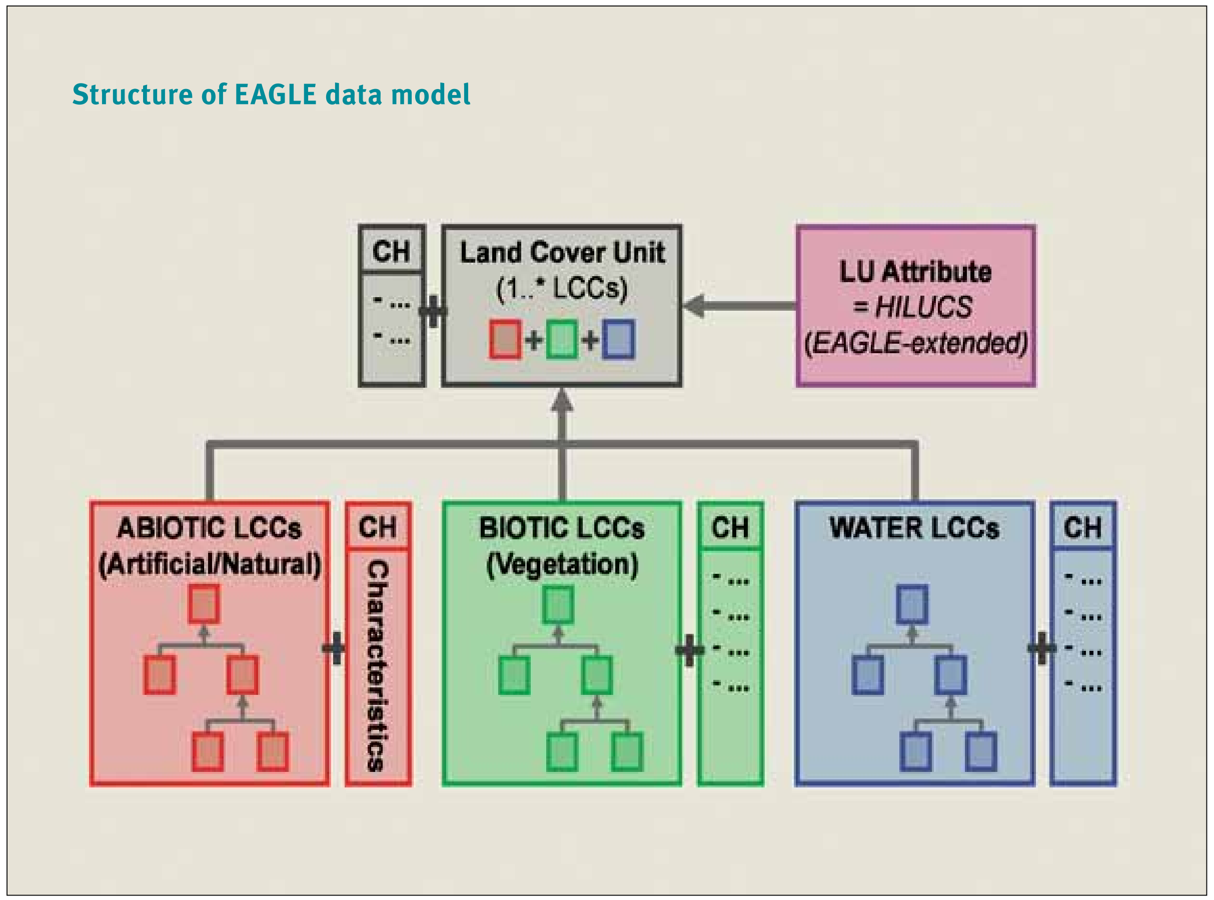


Figure 7. Structure of the EAGLE data model: One single Land Cover Unit (LCU) is formed by one or several Land Cover Components (LCC), further described with characteristics (CH), and with one or many attached Land Use Attributes (LUA). © Stephan Arnold, 2013

Application of the EAGLE concept

The following two main applications are proposed for the EAGLE concept:

- As a tool for semantic comparison and translation between class definitions within one or between several different classification systems. Abstract class definitions can be analysed and decomposed with the model elements in a descriptive and diagnostic manner (without looking at any real landscape scenario).
- As guidance for mapping activities to describe real landscapes by using generic descriptive elements to characterise single land cover units which can then be classified according to an appropriately chosen application purpose and nomenclature.

Figure 8 shows the descriptive decomposing method of LCC applied to an agricultural farm infrastructure with associated land.

The data model itself does not represent another classification system, it rather functions as an intermediate descriptive and decomposing tool for the semantic transformation of data. Additionally, it also can serve as a vehicle for the exchange of information on landscapes between stakeholders and between different nomenclatures.

Recommendation

It is suggested to build on the EAGLE concept with its data model and matrix as a conceptual basis for a future European land monitoring system.

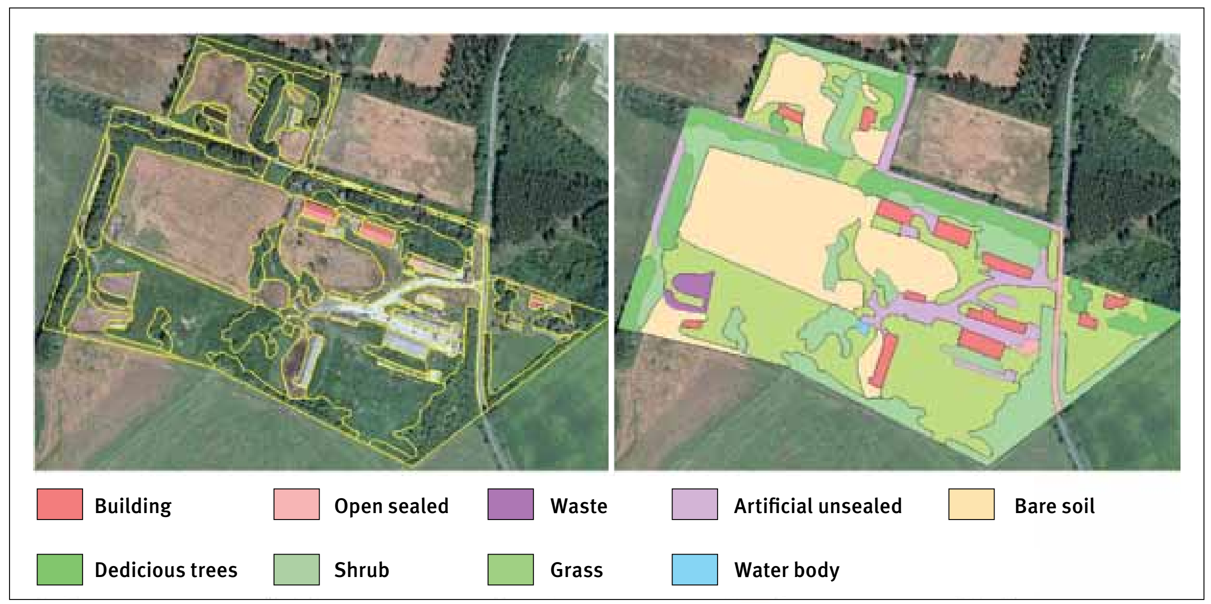


Figure 8. Decomposing an agricultural farm infrastructure with associated land by using Land Cover Components as descriptive elements. Orthophoto: © FÖMI / MADOP 2008

Sharing Land Information

Land information is more than the familiar land cover and land use maps. Land information is also present in many public registers and databases. Examples are special purpose spatial databases for roads, buildings, forestry, agriculture and land use planning. These data sources are maintained and updated through the day-to-day management activities of public authorities. Usually, they are also linked to national data management systems, supported by mandated national agencies, and they are highly standardised. These data sources can be utilised for land monitoring purposes by applying database merging techniques where computers assemble data from existing databases. This approach is not fully explored today, but it does create new opportunities for land monitoring activities at both national and pan-European levels. Findings of the HELM project demonstrate a general willingness among stakeholders to share data and methods in this manner.

Key messages

- Database merging complies with SEIS principles and should be encouraged at national level
- Database merging allows for better national support to European monitoring systems
- Existing cross-national access restrictions are debilitating
- Spatial Data Infrastructures (SDI) must be improved; INSPIRE is expected to be beneficial in the process
- Incomparable cross-national data can still be aggregated at the pan-European level

The opportunities

Database merging is the conceptual basis of the pan-European SEIS initiative under implementation by the EEA. The idea behind SEIS can certainly be made broader to include spatially referenced data. Member states can use national maps and spatial databases to provide European authorities with harmonised data aggregated to a level where they can be included in the pan-European land monitoring systems.

A recent and successful example is the Norwegian land use statistics published by Statistics Norway in 2012. These statistics are not supported by any kind of dedicated data collection but rely entirely on existing data sources. Statistics Norway used GIS software to merge data from topographic maps, land use maps, land cover maps, the building register, the cadastre, and a number of other sources. The resulting composite map was used to calculate the national land use statistics for Norway.

The ancillary data already available in some European countries are sufficiently detailed to allow for the use of database merging as a tool to provide harmonised land monitoring at the pan-European level, e.g., within the framework of CLC. This is possible because the categories used at the pan-European level are fairly broad. The more detailed national or regional code lists may not be individually comparable, but they can still usually be consistently aggregated to the wider pan-European categories. The imprecise definition of

some of the pan-European categories is, in this respect, a more important challenge than the differences between the national code lists.

The obstacles

Database merging is not yet extensively used in pan-European land monitoring. The trend at the national level is, however, a steady progress towards better access to ancillary data and subsequently, also increased use of database merging in land monitoring. The main obstacle is access restrictions, partly linked to the cost of obtaining access to data. Other issues may include the fitness-for-use of the data, data quality, or temporal mismatch between the cycles of the land monitoring activities and update cycle of the ancillary data. Standardisation and cooperation at the national level is therefore a key issue. Issues identified as obstacles to sharing data are presented in Table 3.

Table 3. Obstacles to cross- and supra-national data sharing

Legal	Administrative	Technical
• Access and licensing issues • Sensitive (restricted) information (e.g., LPIS)	• Inter-country harmonisation and coordination • Temporal mismatch (updating cycles) • The “Federal issue” (budgets, ownership, coordination)	• Formats (especially the use of CAD formats by some institutions) • Incompatible spatial resolution details • Missing metadata • Insufficient computer power capacity • Insufficient, outdated quality

Ancillary data is only available in some countries, and data access is in many cases limited. Most countries where ancillary data exists seem to fall into two distinct categories: those with full access and those with no access to relevant ancillary data. Full access seems to be the rule where national or regional SDI has been implemented. Availability of ancillary data is therefore likely to improve as more countries and regions develop their SDIs. The introduction of the INSPIRE directive is expected to accelerate this process and provide better accessibility of ancillary data for public institutions in charge of land monitoring.

Timeliness

The maintenance of ancillary data is usually part of the administrative routines in public authorities. External users may not be allowed direct access to these databases, but access is granted by providing copy datasets produced at certain intervals. The result is a delay between the actual event described in the database and publication of the event to the end-user.

Pan-European land monitoring practiced today is supposed to provide a snapshot of the situation at a certain moment in time. Satellite imagery is therefore the preferred data source. Imagery currently used for land monitoring is, however, usually a mosaic of images obtained at different dates. Realistically, at least for countries with challenging climatic conditions or low sun-angle, these images will always be obtained over several years. Supplementing image interpretation with ancillary data is therefore not necessarily reducing the temporal accuracy in land monitoring, but the temporal aspect will change and has to be interpreted and explained differently.

The method

A study of database merging practices of land monitoring communities in Austria, Finland, Netherlands, Norway, Switzerland, and the UK was carried out by HELM. Despite country-specific practices, considerable commonality exists between the approaches used in these six countries. The core method can be described as a two-phase database merging process (see Figure 9). In its firsts phase existing data is integrated into a production database while in the second harmonised land monitoring data is aggregated by GIS techniques including data retrieval, spatial generalisation, data aggregation, and merging of results into new land monitoring products. The process can be recursive. The two phases can also be implemented independently of each other. Simple generalisation of a single input map is a stand-alone application of the second phase.

In the data integration phase, ancillary databases are rasterised and merged together into a single, integrated dataset with fixed spatial units. Incidentally, many countries seem to use 25 meter pixels as the common spatial units. Data integration is followed by retrieval of layers corresponding to the individual monitoring classes. If the aim is to produce CLC, it is the areas corresponding to each CLC class that are retrieved by queries as new thematic layers from the integrated database. Each of these thematic layers is then geometrically generalised and the results are merged together in a prioritised order.

The HELM inquiries have shown that database merging is already an operational technique and that it is widely used in countries where ancillary data is available and the land monitoring community has been granted access to these data. A small but growing number of countries are also using database merging as part of their contribution to pan-European land monitoring. Database merging has thus already become operational at the pan-European level. The development of the EAGLE semantic concepts for harmonisation between different nomenclatures supports this development in the direction of increased sharing of land information and better national support to the European monitoring systems.

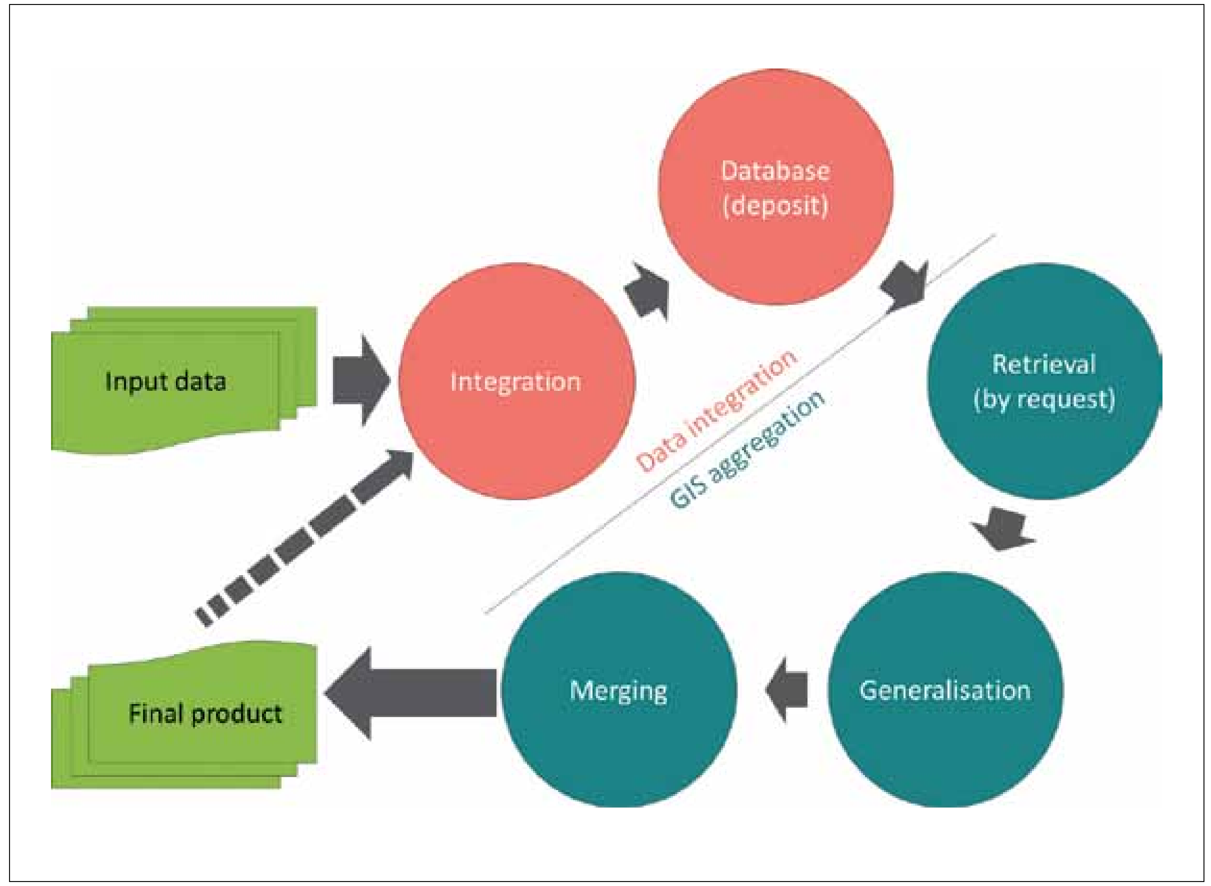


Figure 9. Database merging begins with the integration of existing data into a production database, followed by aggregation of harmonised land monitoring data by GIS techniques including data retrieval, spatial generalisation and merging of data into derived land monitoring products

Synchronisation

Synchronisation of data gathering is an effective tool in the optimisation of resources in monitoring activities, with high potential benefits in the future harmonised European land monitoring. Planning of interconnected land monitoring activities requires well-defined update cycles where well-organised information and data flow satisfy needs in both vertical and horizontal cooperation. Synchronisation of data gathering would include in this context synchronised collection and sharing of both EO imagery (satellite or aerial) and in-situ data.

To ultimately deliver proposals aimed at improving the time- and cost- effectiveness of harmonised European land monitoring, the HELM team has attempted to identify the feasibility and constraints of the synchronisation of data gathering. Three key objectives that must be addressed have indeed emerged: existing and potential user requirements, existing land monitoring cycles, and feasibility and constraints related to synchronisation of data gathering. The following conclusions transpired in discussions with participating HELM partners from different European countries and organisations.

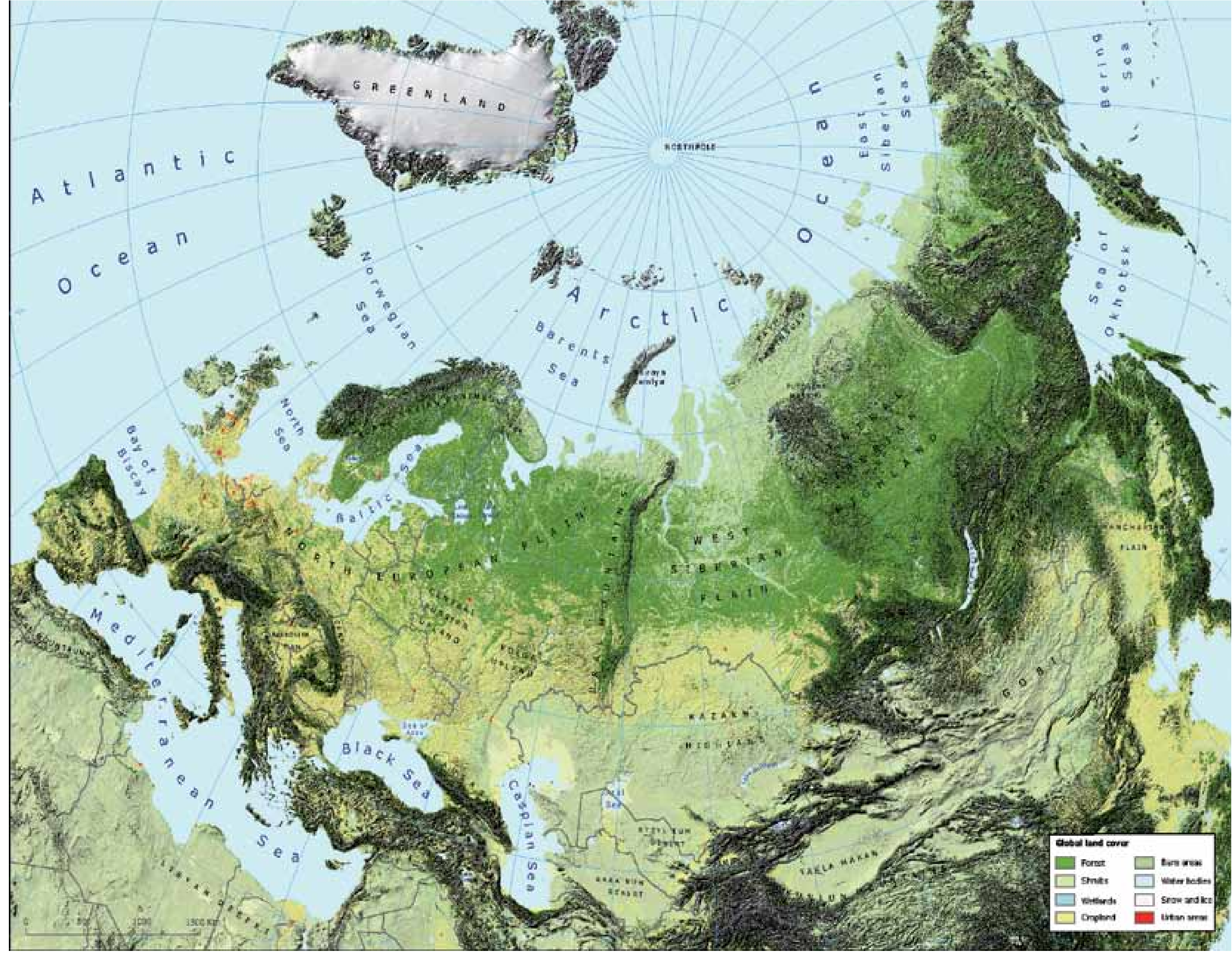
Key messages

- Planning of interconnected land monitoring requires well-defined update cycles
- Optimised update frequency depends on scale and content
- Synchronisation requirements are mostly determined by legal, financial, or political aspects
- Three strategies could facilitate synchronisation: An EU directive, continuous maintenance of maps including change logging, and continuous but cyclic monitoring programmes

Existing and potential user requirements

Findings in existing and potential user requirements of land monitoring activities include ideal (scientific) update frequency dependent on both scale and content. For scale, greater level of geometric detail requires more frequent updates, while continental-level monitoring does not require such frequent updates. For thematic content (class or attribute), more dynamic classes and layers, such as built-up, necessitate more frequent monitoring than most natural classes, such as bare rock. Such classes include slow change processes (e.g., forest growth on northernmost territories) where monitoring frequency is redundant as changes are hardly detectable, even by remote sensing.

In practice, user requirements are mostly determined by legal, financial, and political aspects. Periodic requirements are linked to either reporting obligations or budgetary cycles while non-periodic requirements such as policy audits, production of LULC statistics, requests for particular analysis, etc. rely on data availability. Users whose requests are non-periodic expect a continuous or periodic monitoring programme to keep operating in the "background", providing data on demand at any time for these non-periodic requests.



Existing land monitoring cycles

After identifying a wide range of existing annual, multi-annual and non-periodic land monitoring cycles at global, pan-European, national and sub-national levels, update frequencies of these cycles have been critically analysed. Findings show that national and sub-national systems are closer to scientific optimum (if well financed). However, synchronisation is usually easier to achieve within a single country than between several countries as well as between EU institutions rather than between different administrative levels. Vertical synchronisation (between national or EU endeavours) is mainly driven by the EU (e.g., existing surveys such as CLC and reporting obligations) while horizontal synchronisation (between countries) is occasional.

Synchronisation feasibility and constraints

Identified factors supporting synchronisation feasibility include: open data policy, centralised data acquisition, existence of INSPIRE or EAGLE work groups, existence of interest or thematic work groups, legal obligation for land monitoring, and clear legal assignments.

The following have been identified as constraints to synchronisation of data gathering:

- Missing legal framework or coherent legal mandate, lack of clear legal assignments, and organisational issues concerning level and division of responsibilities including changing responsibilities in ministries and institution;

- Lack of resources or lack of their synchronisation whether funding or staff on each horizontal unit (e.g., in each member state);
- The legal mandate for monitoring is very important, especially in new member states of EU, insinuating a preference to top-down approach which are often impossible to implement;
- Foreign influence may affect both long standing, and well established land monitoring practices as well as emergent, and newly forming practices of member states who had just began land monitoring activities;
- Lack of communication and miscommunication between stakeholders;
- The personal element resulting in building barriers or defending one's own business or carrier;
- Limited or no access to data owned by other ministries or governmental organisations.

HELM recommendations

Based on the experiences summarised above, describing the feasibility and constraints of data gathering synchronisation, three strategies are proposed for facilitating synchronisation:

- An EU directive from central authorities concerning update frequencies with fixed initial dates would be useful (e.g., six years for more complex inventories such as CLC or three years for thematically simple but quickly executable datasets such as HRLs). Once such cycles are set, any activity could voluntarily adapt to them. Synchronisation would be achieved by prolonging one cycle until the initiative is synchronised. Complete annual Sentinel Satellite coverage could support such activities as an encouragement to engage and synchronise.
- Continuous maintenance of maps, including change logging provides data addressing monitoring (change detection) questions where snapshots can be created at any time as required similar to maintenance practices prevalent for topographical datasets.
- Continuous but cyclic monitoring programmes (e.g., five year cycles updating 20% observations each year) are typical of orthophoto campaigns for LPIS and do not allow for the creation of a single-date snapshot. The shortcoming of more frequent updating is the necessity for a large number of staff for short periods. Notwithstanding, more frequent updates would be achievable with continuous activity employing a relatively small number of staff.

In addition to strategies that would facilitate synchronisation, the HELM experts also propose some other useful ideas:

- Define reference data for geometry such as topographic map objects or standard European Lambert Azimuthal Equal-Area (LAEA) grid that can be filled with data from different sources.
- Using a time stamp for data (age of pixel or object) allows users to effectively handle heterogeneous databases. Use of a time stamp may reduce the need to synchronise such heterogeneous datasets and increase motivation to learn how to integrate temporal, spatial and thematic heterogeneous classes.
- LPIS as one of the datasets with the highest update frequency and with wide coverage could be used to update other datasets (can also be used in validation or as geometric reference). Legal constraints should be solved.
- Frequency must be increased for regional level updating, since land management occurs mostly at that level. At the pan-European level only statistics are required.

Alternative Approaches

Existing information at national and regional level throughout Europe can be mobilised in support of land monitoring by applying database merging techniques. The approach implies a bottom-up process where data already existing at national (or sub-national) administrative level are activated in order to provide information at the European level.

The options

Two fundamental aspects of any land monitoring systems are the choices of spatial units and classification system. The spatial units were often comprised of figures attempting to delineate tracts of uniform LULC (polygons). A viable alternative is to use a network (grid) of square cells, independent of the underlying structure of the land. Although many other geometries also are possible (triangles, administrative units, etc.), the polygons and cells are the predominant types.

Classification systems can also be divided into two broad categories. The first category is the predefined list of, sometimes hierarchical, categories: the legend.

> **Key messages**
>
> - HELM's approach allows for bottom-up national to European land monitoring in which local national data and expertise can then be reused in EU products
> - The grid approach is a way forward in European level data handling facilitating access to national data

The second category consists of a range of attributes that, taken together, characterise the land. Examples of such attributes are vegetation, number of buildings, types of buildings and length of roads. Each attribute is measured independently. Together they provide a multifaceted description of the character of the land, which in the next step can be grouped into classes and treated as a legend if necessary. This approach is known as classification by independent diagnostic criteria.

Taken together, the combinations of spatial units and classification systems constitute four different approaches to land monitoring as shown in Figure 10. The familiar CLC system is an example of an approach where uniform polygons are classified according to a pre-defined legend. Many national monitoring systems fall into two other categories: some rely on raster data, often derived from satellite imagery and classified according to a pre-defined legend while others employ independent diagnostic criteria to characterise uniform polygons. The fourth approach offered by this model is that of the grid approach, where grid cells are characterised using a set of independent diagnostic criteria. This approach is considered by the HELM project as an interesting option allowing for high flexibility and with great potential for member state involvement and support in the European land monitoring efforts. This potential should therefore be thoroughly explored.

Bottom-up support

National and sub-national data can support European land monitoring in any of the four approaches outlined above through database merging. Database merging by GIS techniques are already used by some member states to produce CLC. The same methods can be employed should the European land monitoring change strategy and move into any of the remaining three categories of the model.

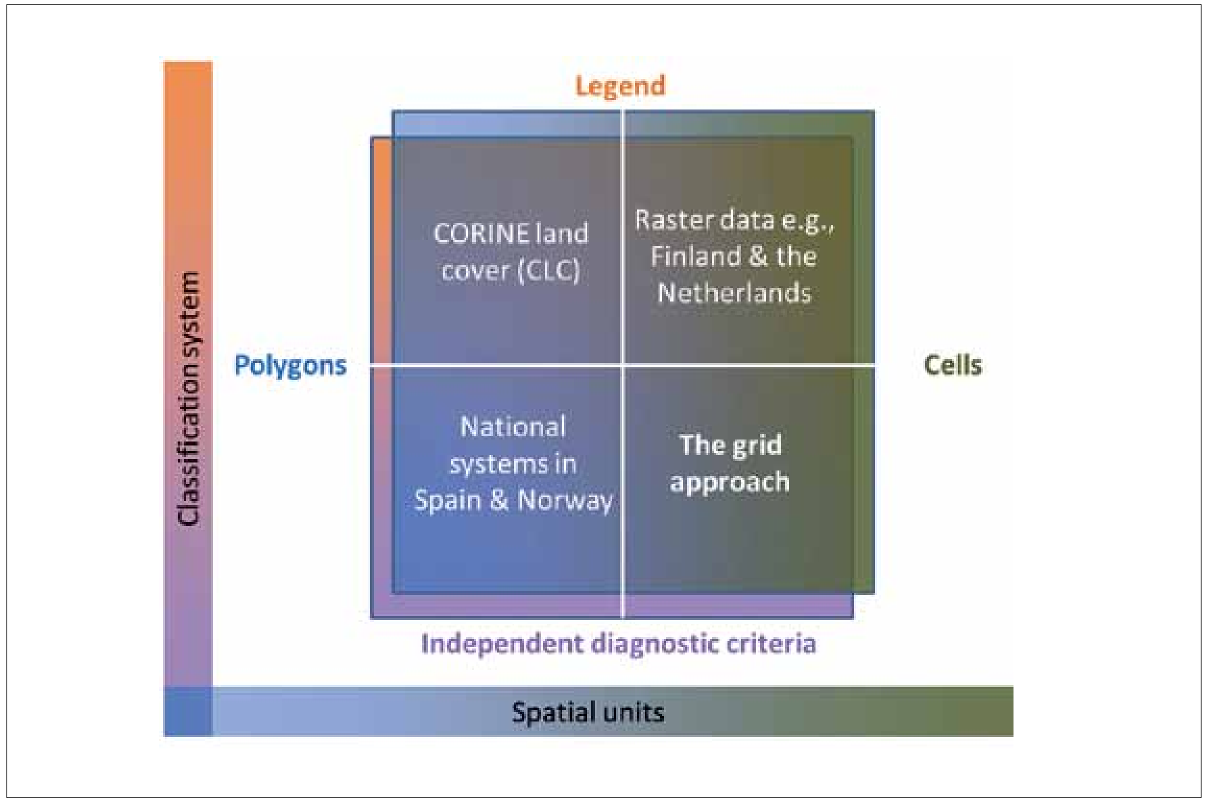


Figure 10. Prevalent approaches to European land monitoring

A survey of existing implementations of database merging by applying GIS techniques revealed that although implementations differ from one country to another, they vary over a common theme (see Figure 11). The methodology consists of a data integration phase and a data aggregation phase (as previously described). Data integration is closely related to national data specifications, but the outcome of the integration phase can bestandardised. The aggregation phase is independent of national specifications.

Standardisation of the database merging techniques is achievable and will contribute to the consolidation of a pan-European monitoring system. Results would be improved by selecting the best practices currently employed among the existing systems. Standardisation will also be helpful for new countries assuming the method. HELM inquiries among the participating institutions, revealed a strong willingness to share methodology and knowledge. Data access is currently animportant obstacle but database merging could replace manual CLC production to become the pan-European methodology for the future as more countries start producing (or gain access to) the necessary national data (see Figure 12).

Database merging by using GIS techniques implies modernising data handling in European land monitoring endeavours. This, however, does not affect the unchanged end product. Development of the end product, currently the CLC dataset, could – indeed, should also be a consideration in any systemic adaptation.

The grid approach

The HELM project identified the grid approach to pan-European land monitoring as a viable and interesting alternative for the future land cover monitoring in Europe. The hierarchical CORINE classification system would, in this case, be replaced by a set of independent diagnostic criteria while the CLC polygons would be replaced by fixed spatial monitoring units of identical shape and size.

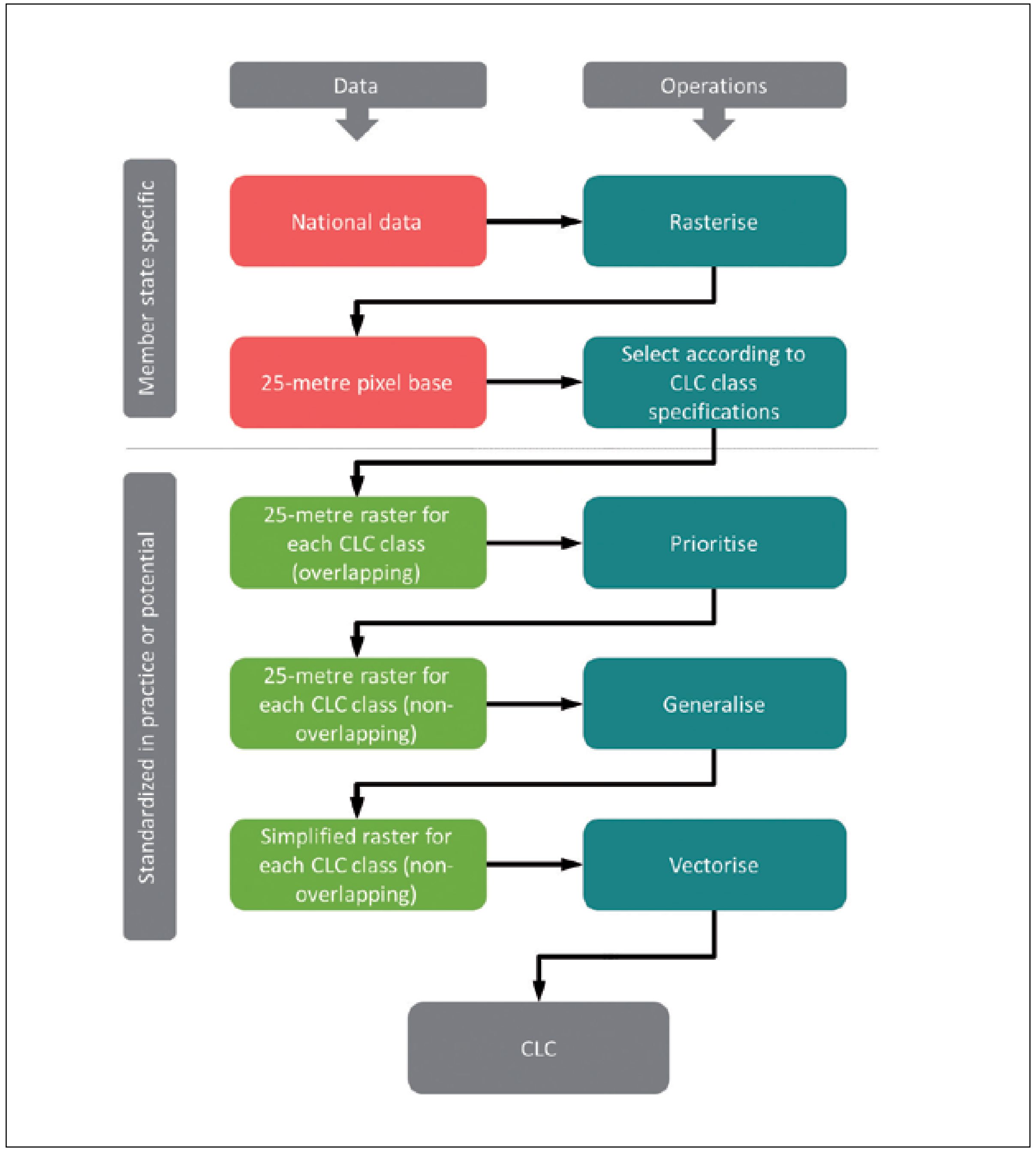


Figure 11. The generic process involved in order to produce CORINE Land Cover by database merging using GIS techniques. Red and green boxes represent data, while blue boxes represent operations. The part above the dotted yellow line will be specific for each member state, while the part below can be (or is already) standardised.

A grid is a spatial data model that consists of a complete partition of a region into a set of non-overlapping spatial units with identical size and shape, usually squares. The visual appearance of the grid cells resembles raster pixels, but their functional character is like that of vector polygons with attached attributes. The attributes are the independent diagnostic criteria, and they replace the hierarchical land cover legend. The grid is populated with information from available sources. This information could include, but is not restricted to, information about land cover and land use. Each land cover class is represented as a separate attribute and the attribute values for a particular grid cell show the proportion of the grid cell covered by the corresponding land cover class.

The grid approach is used by statistical agencies in their production of harmonised European spatial datasets. Some countries also use the grid approach in land monitoring. The grid is, in a sense, a spatial statistical model supporting statistical analysis and modelling and facilitating closer cooperation between sectorial monitoring communities. The experience with grids in the land monitoring community is, however, limited and further testing is required in order to examine its potential, optimised details such as spatial resolution and nomenclature, and secure backward compatibility with the present monitoring system.

Benefits

The analysis of aggregation methods and their application to existing products (CLC), as well as completely new monitoring strategies (the grid approach) revealed that this utilisation of national and sub-national data has a number of benefits, irrespective of the end product.

The approach:

- Allows for a “dual track” system where member states proceed differently according to the availability of relevant data;
- Can benefit from the development of the EAGLE matrix as a European extension of the ISO 19144-2 LCML standard;
- Can utilise the GMES or Copernicus HRLs;
- Is INSPIRE compliant;
- Fosters cooperation between national and pan-European levels;
- Allows for the European monitoring systems to build on continuous monitoring programs at national and sub-national levels;
- Adds cross-border cooperation, testing, and data exchange as possible added benefits for participating countries.

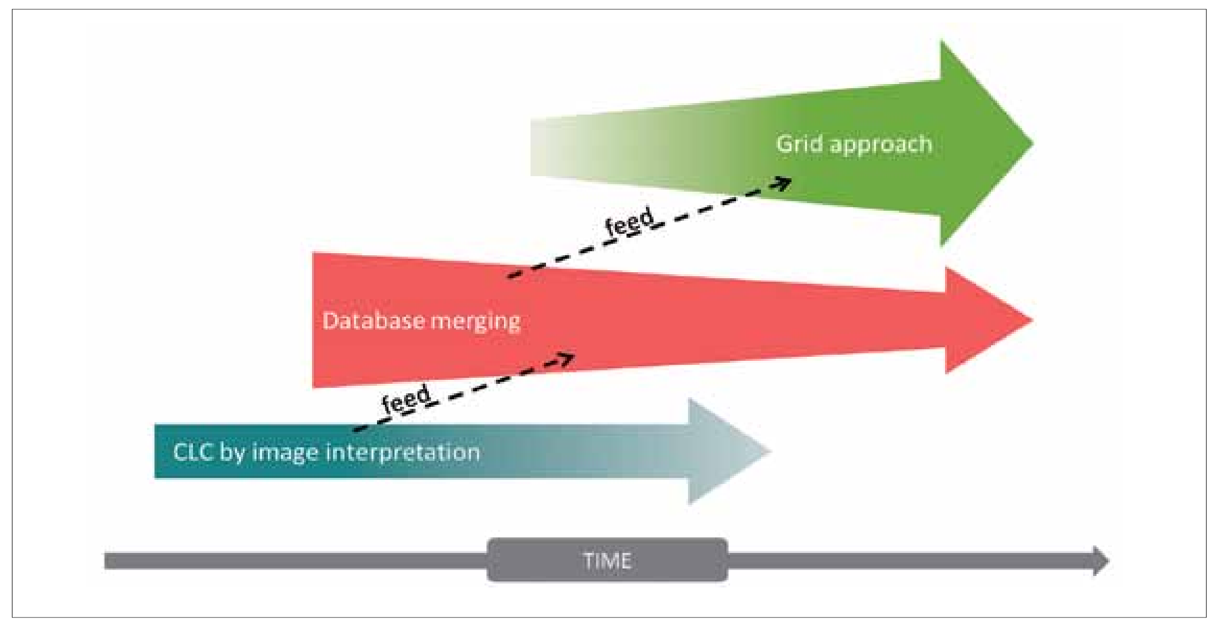


Figure 12. Possible timeline of future European land monitoring where CLC is gradually replaced by image interpretation which, in turn, is also gradually replaced by CLC that is produced following the grid approach to database merging

Perspectives for European Land Monitoring

The revision and modernisation of the current European level land monitoring concept is urgently needed. Obviously, such a revision should be based on a common agreement between the national and European levels. The mere collection of data capturing tools cannot solve such a broad and complex problem. Instead, it requires a systematic and consistent documentation of the knowledge in that domain, which is currently scattered, with each patch developed in isolation.

The land-related paradigm shift requires a transition from the production of ad-hoc land cover maps to the development of a sustainable and reliable land monitoring process based on a common model in line with INSPIRE. Respecting service provider intellectual property rights, production chain concepts should be made accessible to interested customers as a "cook book" of land monitoring approaches, if land monitoring services of European countries aim at achieving interoperability and sustainability.

As products become operational, regularly available, and easily accessible to end users, some forms of quality assurance, certification or standards system would be required, so that users can be sure that the products they acquire actually meet their requirements and that they are sustainable in case of changing service providers.

The precondition for such a new, common approach is the development of a new core land monitoring concept that could replace the traditional CLC, complemented by the new core product that would be as compatible as possible with CLC. The approach for bridging the system from its current situation to a new land monitoring concept would require addressing some administrative as well as technical issues.

Key messages

- The current European land monitoring concept should be modernised based on common agreement between national and European levels
- An integrated European land monitoring system should ascertain backwards CLC compatibility
- Land monitoring products require clear quality assurance measures to instil trust in end users
- A mechanism is needed for information exchange between different levels of land monitoring approaches

Administrative issues raised during the HELM investigation include:

- Full user consultation process to assess actual needs of potential users from (sub-) national to European level, including bottom-up and top-down aspects;
- Existence of (European) stakeholder who takes the lead and national counterparts;
- Sustainable funding mechanism which provides a long-term perspective for the new developments;
- Long-term planning with short-term actions and a continuous dialogue with countries and users.

Technical issues raised during the HELM investigation include:

- Ensuring a minimum level of information (core data) that can be produced by countries that do not currently apply a national land monitoring programme;
- Making best use of information produced at (sub-) national level, building on the potential provided in the bottom-up approach;
- A common frame that would ensure common levels of quality, comparability of outputs, and standards (for production and quality checking);
- Increased production synergies, including a synchronisation of the LUCAS in-situ survey with CLC-HRL;
- Production of HRLs as input to CLC mapping, instead of parallel production;
- Indicators for the evaluation of usefulness and success rate of the proposed solution;
- Central provision of low-level, intermediate products for further development by countries according to their specific needs;
- Most of all, the provision of guidance and common tools, such as a "cook book" collecting best practices of aggregation, generalisation, image processing, a semantic tool (EAGLE matrix) for translation between national nomenclatures, and a standard model (INSPIRE and EAGLE) for creating more detailed national datasets.

Considering differences in land monitoring approaches and the associated levels of technical capacity of national monitoring programmes (e.g., SIOSE in Spain, DLM-DE in Germany or LISA in Austria), it is of particular important to provide a mechanism which would allow these different approaches to co-exist and properly communicate with each other and to exchange data and information among the different levels. Here the EAGLE concept offers one of the first and important contributions for an operational tool to enhance semantic translations of and between national and European land cover classifications.

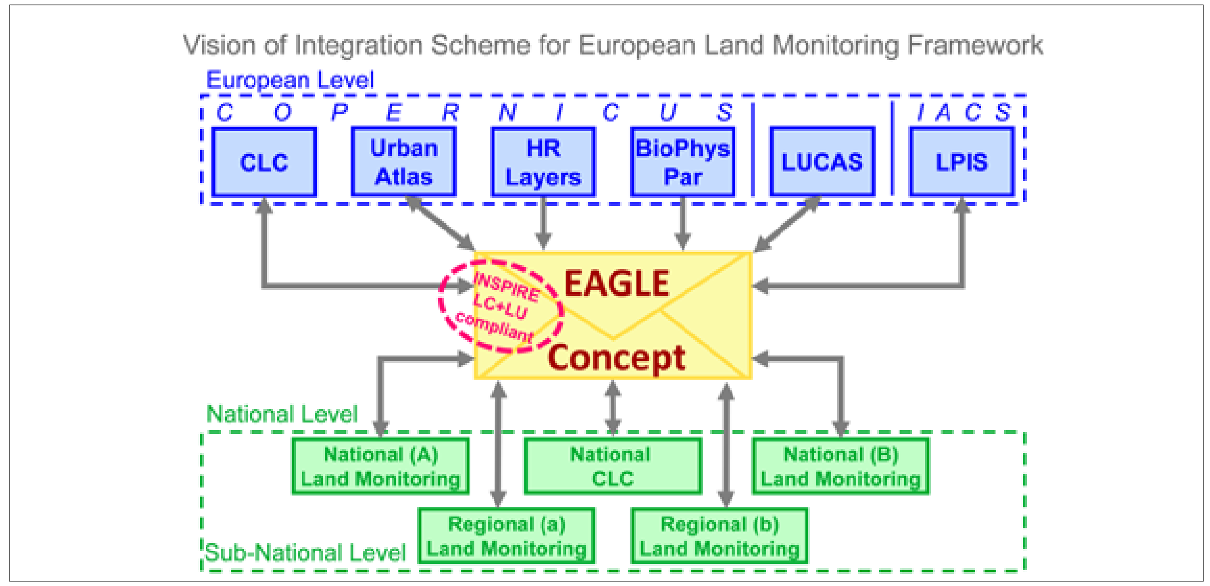


Figure 13. Vision of an integration scheme for a European land monitoring framework with the EAGLE model as the central vehicle for data integration and exchange of land information. © Stephan Arnold, 2013

Conclusion – What's Next

The HELM Roadmap

Projects are temporary undertakings. HELM has ended in December 2013, but the process of harmonising European land monitoring is an ongoing activity. Moreover, many of the HELM participants are also members of EAGLE which will continue its collaboration.

The currently negotiated regulation of the European parliament and of the council establishing the Copernicus programme states that

Copernicus data should maintain coherence with Member States' spatial reference data and support the development of the infrastructure for spatial information in the Union established by Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Copernicus should also complement the Shared Environmental Information System (SEIS) and Union activities in the field of emergency response.

The HELM roadmap for a future integrated European land monitoring system provides an opportunity to put this statement into action. Drawing pan-European datasets from nationally produced land monitoring data would be the optimal way to ensure that the pan-European datasets are compatible with member states reference data and that data are kept close to their source and used for several purposes, as stipulated by SEIS. Furthermore, the regulation states that

Copernicus should also make use of the available in situ data provided, namely, by the member states.

Several member states already include in-situ data in their land monitoring products, this is especially true for aerial photography (which in the Copernicus context is considered in situ), but, to a degree also to ancillary data. Thus, utilising nationally produced land monitoring data to derive pan-European data from them would be the optimal way to make use of national in situ data.

Obviously, users can most effectively be involved in Copernicus through continuous collaboration, participation, and active involvement in the programme – much more than by merely consulting them through commercial data providers and subsequently delivering ready-made data products to them. Thus, the concept to conduct pan-European land monitoring by combining top-down and bottom-up procedures is in line with the regulations' statement that

Copernicus should be user driven, thus requiring the continuous, effective involvement of users, particularly regarding the definition and validation of service requirements.

The new Copernicus programme, then, as the operational successor of GMES, provides a framework which supports the opportunity to put the HELM concept into action, if the European Commission, as the programme owner, takes the first step to initiate this endeavour. As is shown in this report, harmonising land monitoring across Europe is a long-term process that requires leadership and endurance, and, to that end a well defined joint programme framework. For the near future, Copernicus is well suited to offer such a framework until sufficient results are achieved that justify the establishment of a more specific legal framework such as a thematic strategy that requires operational land monitoring in the member states.

The long-term process of increasing maturity of European land monitoring, as envisaged by HELM and described in this report, is best addressed in a step-wise

manner that demonstrates to all stakeholders involved which added values they can generate when they place stronger emphasis on common interests than on individual ones. Aligning national undertakings of any kind is a complex participatory process. The willingness to collaborate and to forgo some independence requires that the benefits are clear for each participant – which is true for the stakeholders in the member states and at European level alike.

Increasing maturity of European land monitoring involves an increasingly strong alliance of national land monitoring systems. Nevertheless, the process must consider the preservation of their distinctiveness and should not attempt to erode their autonomy. The long-term goal thus is to achieve a well balanced situation, in which national land monitoring solutions take care of national and sub-national specifics. These national land monitoring systems would be based on compatible concepts and data models (alignment), and they would provide the technical solution towards a European umbrella (integration). Needless to say that not all of Europe will go through such a process in the same manner, but countries will move in different paces.

Finally, projects typically end with the conclusion that more research is needed. Indeed, in conjunction with Copernicus programming, HORIZON 2020 should issue a dedicated call to foster the still needed further development of the land monitoring harmonisation process along the lines of the above described concept to increase the maturity of European land monitoring. The work of the EAGLE group is not sponsored by any funding source. Thus, an external source is needed. Such a dedicated call would be beneficial for all parties involved, the organisations conducting land monitoring in the member states, and, not least, European stakeholders whose needs could then be most efficiently addressed by the proposed synergy of a decentralised (bottom-up) and centralised (top-down) production processes of land use and land cover data.

General Information

Consortium members

The following organisations form the HELM project consortium:

Core team

Environment Agency Austria (EAA) – Austria (Project coordination)

Czech Environmental Information Agency (CENIA) – Czech Republic

Finnish Environment Institute (SYKE) – Finland

Institute of Geodesy, Cartography and Remote Sensing (FÖMI) – Hungary

European Centre for Research and Financing (EuCRF) – Israel

GeoVille Environmental Services (GEOVILLE LUX), Luxembourg

Norwegian Forest and Landscape Institute (NFLI) – Norway

Portuguese Geographic Institute (IGP) – Portugal

National Geographic Institute, Spain (IGNE) – Spain

Autonomus University of Barcelona (UAB) – Spain

European Forest Institute (EFI) – Finland

General consortium

Fotec Research and Technology Transfer (FOTEC) – Austria

Remote Sensing Application Centre (RESAC) – Bulgaria

Flemish Geographical Information Agency (FGIA) – Belgium

GISAT S.R.O (GISAT) – Czech Republic

French National Mapping Agency (IGNF) – France

Federal Agency for Cartography and Geodesy (BKG) – Germany

Informus (INF) – Germany

National Land Survey (LMI) – Iceland

Institute for Environmental Protection and Research (ISPRA) – Italy

European Academy Bozen/Bolzano, Institute for Applied Remote Sensing (EURAC) – Italy

Alterra, Wageningen University and Research Centre (ALTERRA) – The Netherlands

Department of Natural Resources, Danube Delta National Institute (DDNI) – Romania

Federal Office for the Environment (FOEN) – Switzerland

Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) – Switzerland

Specto Natura (SN) – UK

Extended consortium

Additionally, a number of supporting organisations contributed to the success of the project without being formal project partners, members of the extended consortium include the AGEA (Italy), EA ECNIS (Bulgaria), EEA, EvroGeomatika (Serbia), FAFS (Bosnia & Herzegovina), GSM (Montenegro), IEPA (Ireland), IGC (Poland), JNCC (UK), LSIA (Latvia), MEDAD (France), MEPA (Malta), MoEF (Turkey) and UBA (Germany), which brings together representatives of both member states and the above mentioned organisations.

Additionally, the HELM project also received contribution and support from its European Stakeholders Team, which consists of representatives of European organisations that intend to use pan-European GMES land cover and land use data sets. They participate in HELM at their organisations' expenses and contribute to the deliverables on a voluntary basis.

The HELM project consortium extends its sincere thanks to all these organisations as well as to all participants in project workshops and discussions for their valuable contributions.

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