DECOVER 2 – THE GERMAN GMES EXTENSION TO SUPPORT LAND COVER DATA SYSTEMS: STATUS AND OUTLOOK

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ABSTRACT

Currently there are different national approaches in Europe to cope with the increasing demand for up-to-date land cover information using remote sensing techniques. Most of them are related to the Corine Land Cover mapping system and service developments within the Global Monitoring for Environment and Security (GMES) initiative. While these programs address the needs at a pan-European scale, the DeCOVER project serves as a national extension to develop remote sensing based services that address land cover/use systems in Germany.
Within this paper the DeCOVER Core Service, a change detection based approach, as well as the first specification of the DeCOVER Thematic Services addressing agricultural and environmental monitoring needs will be presented.

1. DECOVER IN THE CONTEXT OF EUROPEAN LAND COVER DATA SYSTEMS AND GMES

The CORINE Land Cover data set is currently the only available homogenous land cover/use (LULC) data set covering all of Europe. It provides 44 LULC classes at a scale of 1:100.000. There are different approaches in Europe to address the update of this European CLC data using nationally adapted classification approaches. Some countries developed automated processes using aerial photographs or satellite images to derive updated LULC information.
In Great Britain for example, the UK Land Cover Map has undergone an evolutionary process moving from a pixel-based classification towards an object-based approach [1]. Using a generalized OS MasterMap© by the national mapping agency, they combine the advantages of very detailed topographic information and very accurate geometries with an efficient update process using satellite information. In drawing on the same base geometry they increase the potential user community and overcome the problem of using unique spatial structures if related entirely to Earth Observation data [2].

To produce the Finish CLC map for 2006 an automated interpretation of satellite images and data integration with existing digital map data were also applied. Additionally, specific classes were interpreted manually with the aid of the available IMAGE2006 satellite layer and ancillary data [3].

Less automated processes rely on visual interpretation to produce very detailed thematic classes beyond the requirements by CLC. The Portuguese Land Use and Land Cover Map of Continental Portugal for 2007 (COS2007) for example is a very detailed LULC map based on aerial photography and visual interpretation [4] with up to 193 classes at five classification levels, where the first three levels are in line with CLC.

The German CLC2006 was performed similar to 1990 and 2000 using a visual interpretation of satellite images and ancillary data in line with the European interpretation guidelines [5, 6]. It was based on the IMAGE2006 satellite image layer (made up of SPOT 4, SPOT 5 and IRS-P6 satellites images) and additional LULC information made provided by the FP7 project Geoland, GSE Forest Monitoring and the national DeCOVER phase 1 [7].

Currently there are developments in Germany to combine the advantages of the existing very detailed national topographic reference data set ATKIS© with remote sensing techniques based on satellite images to provide future CLC updates. For this, the existing ATKIS© is transformed and generalized to a digital landscape model compatible with the CLC nomenclature and updated with satellite information [8]. This so called Digital Landscape Model for Federal Purpose (DLM-DE) was developed by the German Federal Agency for Cartography and Geodesy in corporation with the Federal Environmental Agency. It is regarded as a German contribution on the way to interoperability between national and pan-European geoinformation data sets [8].

In the context of GMES (Global Monitoring for Environment and Security), a joint initiative of European Commission and European Space Agency, several services are developed to provide spatial information to support the monitoring and reporting obligations of European directives ([9], www.gmes.info). The GMES initiative is currently stepping from a Research & Development stage to an operational phase. Funds from the Seventh Framework Programme (FP7) are contributing to the development

of space infrastructure, as part of the ESA GMES space component program, and financing pre-operational services in the fields of land monitoring, marine monitoring, atmosphere monitoring, emergency response, security and climate change adaptation and mitigation. From 2011 to 2013, operational GMES services should be provided on a larger scale, building on and complementing development activities, according to a commission proposal [10], which has been recently approved by the European Parliament. It foresees actions in the following fields:
(a) emergency response services;
(b) land monitoring services;
(c) measures to support take-up of services by users;
(d) data access;
(e) the GMES space component.

DeCOVER serves as a national extension of the GMES initiative. It was initiated to provide land cover information adapted to German user needs and to support existing land cover/use data systems at regional, national and international level using innovative remote sensing and data modelling techniques.

- The ATKIS/DLM data misses required information depth and timelines especially for vegetated land cover classes
- The BNTK data sets provide high-detailed information for environmental monitoring, but do not cover all of Germany consistently and their updates are too cost-intensive to guarantee regular updates.

These outcomes served as starting point to define the research objectives of DeCOVER phase1 (2006-2008), funded by the Federal Ministry of Economics and Technology (BMWi) via the German Aerospace Center (DLR). Phase 1 thus focussed on (1) the analysis of existing user requirements in relation to existing monitoring and reporting obligations, (2) to employ interoperability techniques to establish semantic links between existing land cover/use systems and (3) to demonstrate remote sensing processing capabilities to produce update information for currently available European and national land cover/use systems.

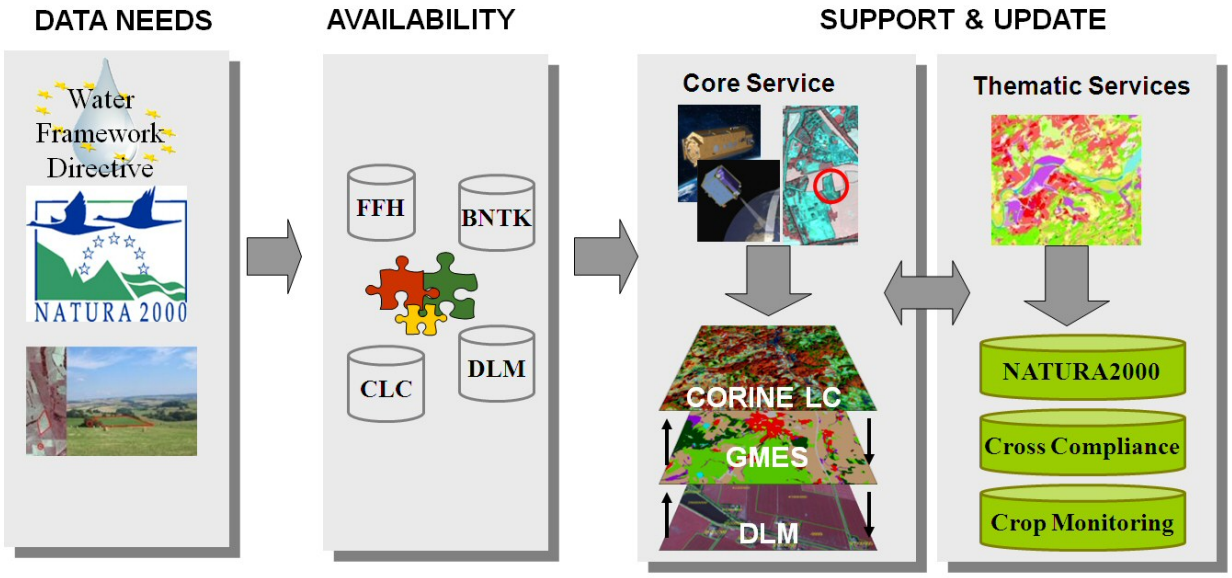

Figure 1. Addressing data needs with harmonized DeCOVER Services

A User Requirement study performed during an initial DeCOVER preparation phase over six months in 2005 revealed that available data sets, such as the European Corine Land Cover (CLC), the German topographic reference data set (ATKIS/DLM® as well as Biotope and Land Use Type Mapping Schemes by the Federal States (BNTK) provide important information for different applications, but have several limitations:

- The European CLC is neither sufficient in its thematic and geometric resolution at a regional to national level.

Within DeCOVER 2 (2009-2012), these developments will be continued, integrating the now operationally available remote sensing satellite systems RapidEye and TerraSAR-X. The DeCOVER 2 developments will strongly support the current national developments to provide a national harmonized LULC data set such as the DLM-DE and link international developments in the light of GMES and its operational phase by providing (Figure 1):

- Change information based on satellite image information (DeCOVER Core Service)

- Link this information to existing national topographic reference datasets
- Integrate European data models and provide semantic links to these models
- Provide additional thematic data services not covered by existing European LULC data services to support national and regional monitoring in the field of agriculture and environmental monitoring (DeCOVER Thematic Services)

The following chapters will provide more information on the DeCOVER Core Service approach and the specification of the DeCOVER Thematic Services.

2. THE DECOVER 2 CORE SERVICE: A CHANGE DETECTION APPROACH

Land cover change can be detected using remote sensing image information using a variety of methods [11, 12]. The existing approaches can be summarized into various categories (see [13] for an overview). Change detection methods can for example be grouped roughly into two types: classification comparison and direct comparison [14]. Another suggestion is to classify the processes into three categories, including pixel-based, feature-based and object-based change detection [15]. Yet, common to all approaches is the basic premise that the process can identify change between different (two or more) dates, that is uncharacteristic of normal variation using remote sensing data.

The usage of change detection techniques is fundamental principle within DeCOVER. The DeCOVER Core Service will be developed to provide change information based on vector reference data and newly available satellite image data. It follows a stepwise object-based change detection approach complemented by interoperability tools (*Figure 2*). First the user data as update reference information will be sematically transformed to a common DeCOVER nomenclature developed during DeCOVER phase 1 consisting of 39 LULC classes [16].

During the following initial change detection process images from the newly available German satellite systems RapidEye© (RE) and TerraSAR-X© (TSX) will be used as preferred image data source. The German RapidEye system is a constellation of five identical optical satellites with a re-sampled ground resolution of 5m and spectral information in the Blue (440-510nm), Green (520-590nm), Red (630-690nm), Red-Edge (690-730nm) and Near-Infrared (760-880nm) channel. The TSX system is a new radar satellite operating in the X-Band in different acquisitions modes. For DeCOVER data acquired in Stripmap mode with a ground sampling distance of about 3m is applied. Both data sources are provided as standard data products orthorectified to UTM32N/WGS84. The optical RE data is additionally atmospherically corrected using ATCOR-2 standard procedures.

For the initial change detection step within the DeCOVER Core Service two development scenarios

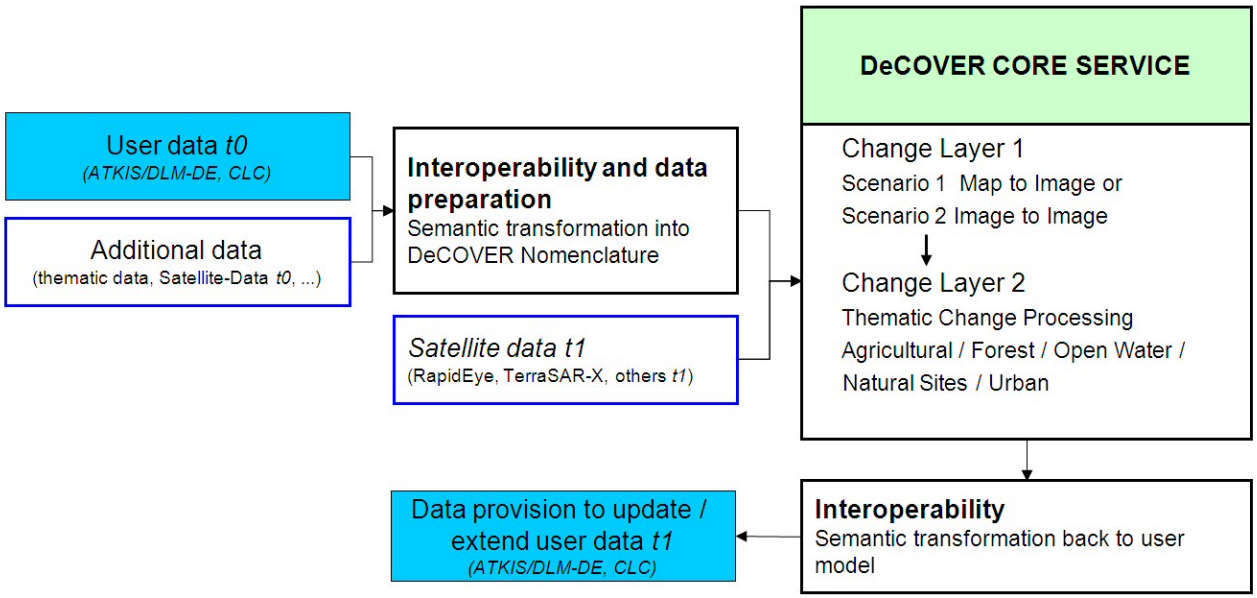

Figure 2. DeCOVER Core Service Workflow

have been defined based on different data availabilities:

- Scenario 1: Vector Map-Image change

- Scenario 2: Image-Image change

The current research focus lies on Scenario 1, because due to the new satellite systems no complementing image information is available for archive user vector data to be updated. But more important, to establish a more flexible process chain, it cannot be assumed that all vector data to be updated come with corresponding satellite image data. The following assumptions are therefore made for scenario 1:

- for the reference year t0 there is no raster image data available
- there is a vector data t0 to be updated
- for the new update year t1 there is raster image data available (mono- or multi-temporal TSX and/or RE)

The change classification within DeCOVER is based on a comparison between the a priori defined LULC class from the reference vector data set and object signatures (spectral information and derived indices) from the satellite images. This comparison will be performed for each reference feature object. Based on a knowledge database the spectral and texture object characteristics will be compared to expected ranges (reference values) adapted to the image under investigation. The reference values will be calculated using the a priori information from the vector reference data, which will be statistically analysed using data mining tools. This approach is based on the assumption that for the majority of object features under investigation there has been no change. Additionally expert knowledge about change probabilities will be modelled and included in the classification process. This is based on the assumption, that certain LULC changes are more likely to occur (e.g. conversion from arable land to urban structures) than others (e.g. arable land to open water) [17].

The outcome of this initial change classification process is a change layer (Change layer 1) with change probability attributes attached to each feature object in the t0 user data, keeping the original vector geometries (Figure 2).

In a second classification step a thematic change classification including geometry changes is performed. For this, the Change Layer 1 is passed on to subsequent processing teams. The user reference data t0 will at this point be split up into different “processing parcels” based on the original LULC class and geometries in the user data, i.e. former agricultural feature objects flagged with a high change probability will be passed on to the agricultural processing team. The following LULC class aggregation is made to separate the user data into the following processing parcels: a) agricultural b) urban c) forest d) natural habitats e) open water classes. It is important to note here, that this subsequent processing system can be located at different physical places and be performed by a different research team or service provider.

The thematic approaches to classify the final change classes are all object-based. Depending on the thematic class, mono- or multi-temporal classification will be performed employing RE and/or TSX data. A description of the different approaches is not part of this publication. During the classification processes the initial user feature objects will be sub-segmented and classified based on the new image data while keeping the original vector geometry to allow an integration and comparison with the original t0 data. Processed data from each thematic processing theme is then combined again to the integrated Change Layer 2 containing all thematic changes, while retaining original (plus additional caused by true changes) geometries.

During the final processing step of the DeCOVER Core Service, the updated t1 user data will be semantically re-transformed to the user data model and can then be provided as physical change data (i.e. as ESRI Shape data) or via standardized Web Services.
The DeCOVER Core Service will be implemented on selected test sites throughout Germany to reflect different natural settings and conditions. During DeCOVER2 the process chain developments will be based on ATKIS/DML-DE and CLC as user reference data to be updated. For validation the service will be evaluated by reference users as well as blind-tested in an additional test site (*Figure 3*).

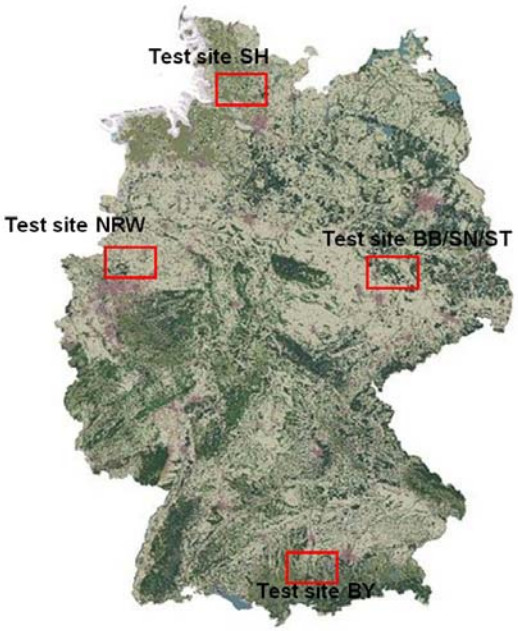

Figure 3. DeCOVER 2 test sites in Germany

3. DECOVER 2 THEMATIC SERVICES

In addition to the DeCOVER Core Service, more detailed thematic change information is required for existing monitoring and reporting obligations by the public authorities at a national and regional level in Germany. Therefore thematic DeCOVER Services for agricultural and environmental monitoring will be developed and demonstrated in DeCOVER 2.

3.1. Agricultural Services

The European Union's common agricultural policy (CAP) was changed in 2003. As part of this reform a control of cross compliance of the applications for subsidy was introduced. This includes information on agricultural conditions and landscape elements required under the so called Cross Compliance mechanism [18, 19], in order to:

- minimize erosion
- maintain organic soil content and soil structure
- avoid the encroachment of unwanted vegetation on agricultural
- keep landscape features, including, where appropriate, hedges, ponds, ditches trees in line, in group or isolated and field margins

The further DeCOVER 2 developments will be based on an existing object-based, hierarchical classification method [20, 21]. This approach is based on the analysis of spectral features, image texture, geometry features using GIS a priori knowledge from existing landscape element inventories and existing land parcel identification systems (LPIS). The current mono-temporal methodology is based on VHR data and will be further adapted to also employ multi-temporal RE data (Figure 4).

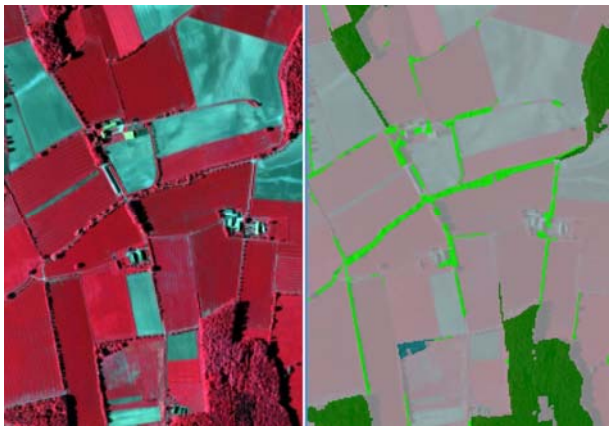

Figure 4. Classification example (right) of landscape elements on VHR data (left, Ikonos data rescaled to 5m)

The Integrated Administration and Control System (IACS) is the main administration tool for managing and controlling subsidy payments to European farmers defined in the Council Regulation (EC) No.1782/2003 [18]. The technical implementation of IACS is guided by the Commission Regulation (EC) No. 796/2004) [19]. Part of this system is the establishment and maintenance of a Land Parcel Identification System (LPIS) as an identification system for agricultural parcels.

The approaches used for the creation of the LPIS differ from country to country. They depend on the reference parcel defined, the reference data available (orthophoto, cadastre, topographic maps) and local agriculture conditions for example. Because agricultural parcels can change due to construction activities and changing management, and by this be no longer eligible for subsidy payments, the LPIS has to be updated regularly. The following reference parcel criteria can be analyzed via remote sensing in this context:

- it is accessible for agriculture activities (cropping, grazing, etc..) in that vegetation is growing or can be grown on the land
- obstacles either man-made or natural are not blocking the access and use of the land

Using multitemporal RE data these criteria can be verified (*Figure 5*). The change indication can then be used to update existing LPIS geometries using very high resolution image data, as required by the regulations.

Figure 5. New road construction requires LPIS reference parcels to be updated (outlined in red, confirmed parcels solid yellow, background image RGB RapidEye)

3.2. NATURA2000 Services

The most important instruments for European environmental protection are the Habitats Directive [22] and the directive on the conservation of wild birds [23]. Protected sites out of both directives form the NATURA 2000 network of protected sites. For these sites regular monitoring information on habitat changes and threats are required.

The application of spatial information and indicators to detect habitat changes using remote sensing techniques has been applied successfully using multi-temporal satellite image data [24, 25]. Especially Very High Resolution data has been proven successful for the monitoring of NATURA 2000 sites [26]. Within selected test sites in Germany processes adapted to the monitoring requirements of the different federal states will be developed, following an indicator-based approach. Currently field data are collected (*Figure 6*) and the evaluation schemes are analyzed for appropriate application of remote sensing indicators. The focus is here to analyze the potential of multitemporal RE and TSX data applied to these very detailed thematic levels.

According to the Habitats Directive monitoring regulation, the protected habitats within the so called Special Areas of Conservation (SAC) have to be assessed according to evaluation schemes defining three quality condition states. These evaluation schemes define criteria to judge the quality for every protected habitat type. Some of these parameters can be analyzed using remote sensing based spatial indicators. The evaluation scheme for the habitat type 4030 (European dry heaths) for example includes information on the percentage of non-vegetated ground and maturity levels of heath growth, which can be classified using remote sensing data.

Figure 6. Biotope data (top) and reference ground samples in one of the DeCOVER FFH test sites

4. CONCLUSIONS AND OUTLOOK

The DeCOVER 2 research developments can be seen as a national extension to the GMES activities providing LULC information services to decision makers at different scales. In its project setup and objectives it also supports the current German approach to establish a national harmonized digital landscape model (DLM-DE), based on the topographic reference data model ATKIS/Basis-DLM© using remote sensing information.

To provide the support for GMES and national LULC initiatives, a multistep change detection process chain is being developed and demonstrated over selected test sites in Germany. It uses multi-temporal satellite data as being provided by RapidEye and TerraSAR-X to detect changes based on existing reference geometries. The first implementation of the DeCOVER Core Service will start in July 2010 to be available for validation in the beginning of 2011.

In addition to the DeCOVER Core Service, thematic services related to agricultural and environmental monitoring needs will be developed and demonstrated on selected test sites, too. DeCOVER 2 focuses here on the reporting obligations of the Cross Compliance mechanism as well as the FFH directive and their national implementations. First implementation results of the DeCOVER Thematic Services will be available towards the second quarter of 2011 via standardized Web Services.

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