

DIGITAL LANDSCAPE MODEL DLM-DE – DERIVING LAND COVER INFORMATION BY INTEGRATION OF TOPOGRAPHIC REFERENCE DATA WITH REMOTE SENSING DATA

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ABSTRACT:

Within the surrounding frameworks of the programme Global Monitoring for Environment and Security (GMES) (EEA, 2006) and the Directive for the Infrastructure for Spatial Information in the European Community (INSPIRE) (EU, 2007) the Digital Landscape Model for Federal Purpose (DLM-DE) can be seen as a German contribution on the way to interoperability between national and pan-European geoinformation data sets. This paper describes the concept of the “DLM-DE”, which was developed by the German Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie - BKG) in corporation with the Federal Environmental Agency (Umweltbundesamt – UBA), and its implementation plan. It also aims at pointing out the potential benefits and constraints of the deriving of CORINE Land Cover (CLC) data from the DLM-DE as an enhanced alternative to the conventional method proposed by the European Environmental Agency (EEA). The concept of the DLM-DE embodies the integration of topographic reference data (in-situ data) with thematic remote sensing data. Thereby the ATKIS Basis-DLM functions as the basic working data set. Referring to a certain reference year (2009) it shall be updated and verified by adding land cover information through semi-automated analysis and interpretation of mid- to high resolved satellite imagery. In preparation of deriving the CLC-data the ATKIS feature type catalogue (FC) is compared with the CLC-nomenclature by forming a semantic transformation table and – if necessary – modified due to missing CLC-classes. After a preliminary CLC-coding of all DLM-DE features according to the semantic transformation look-up table they are updated or verified through remote sensing methods. The result will be a high resolved spatial data set, which is capable to map the land cover information of Germany referring to European nomenclature with so far unequalled accuracy.

ABSTRACT:

Im Zusammenhang mit dem Programm Global Monitoring for Environment and Security (GMES) (EEA, 2006) und der EU-Richtlinie zur Schaffung einer Geodateninfrastruktur in der Europäischen Gemeinschaft (INSPIRE) kann das Digitale Landschaftsmodell für die Zwecke des Bundes (DLM-DE) als ein deutscher Beitrag auf dem Weg zur Interoperabilität zwischen nationalen und pan-Europäischen Landbedeckungsdatensätzen gesehen werden. Dieser Artikel beschreibt das Konzept des “DLM-DE”, das vom Bundesamt für Kartographie und Geodäsie (BKG) in Abstimmung mit dem Umweltbundesamt (UBA) entwickelt wurde, und seine Umsetzung. Es soll dabei auch auf die möglichen Vorteile und Einschränkungen der Ableitung von CORINE Land Cover (CLC) Daten aus dem DLM-DE als eine verbesserte Methode alternativ zu der bisher angewandten und von der Europäischen Umweltagentur (EEA) aufgestellten Methode eingegangen werden. Das Konzept des DLM-DE beinhaltet die Integration topographischer Referenzdaten (In-Situ Daten) mit thematischen Fernerkundungsdaten. Dabei dient das ATKIS Basis-DLM als der grundlegende Arbeitsdatensatz. Es soll durch halbautomatische Analyse und Interpretation von mittel bis hoch aufgelösten Satellitenbilddaten bezogen auf ein bestimmtes Referenzjahr (2009) aktualisiert und verifiziert und so um eine Landbedeckungskomponente zum „DLM-DE“ angereichert werden. Zur Vorbereitung der Ableitung von CLC-Daten wird zunächst der ATKIS-Objektartenkatalog (OK) mit der CLC-Nomenklatur verglichen, eine semantische Transformationstabelle erstellt und der OK – wenn nötig – um fehlende Analogien zur CLC-Nomenklatur ergänzt. Nach der vorläufigen CLC-Codierung aller DLM-DE-Objekte werden diese gemäß der erstellten Transformationstabelle durch Methoden der Fernerkundung aktualisiert bzw. verifiziert. Das Ergebnis „DLM-DE“ wird ein hoch aufgelösten Geodatensatz sein, der es erlaubt, die Landbedeckung für Deutschland nach europäischer Nomenklatur mit bisher unerreichter Genauigkeit abzubilden.

1. INTRODUCTION AND BACKGROUND

1.1 Land Cover Mapping in Europe

Europe is coalescing, not only in political and economic terms, but also in the field of geoinformation und remotely sensed environmental monitoring, which is gaining in importance for spatial planning and decision making. This is reflected in the reporting commitment of the member states to the EU. To fulfill this duty and to be able to compare geoinformation across Europe regardless of various national data specifications while referring to a certain common time stamp, the project for Coordination of Information on the Environment (CORINE)

was launched by the European Commission (EC) in June 1985 (EU, 1985). Based on the interpretation of satellite imagery the first seamless pan-European data set on land cover was generated for the reference year 1990. Meanwhile 38 member states and neighbouring countries of the EU participate in this project, while the European Environmental Agency (EEA) functions as the managing and coordinating institution, assisted by the European Topic Centre for Land Use and Spatial Information (ETC-LUSI). The UBA is the national reference centre (NRC) and acts as the contact point for the EEA and is responsible for the management and coordination of CLC in Germany.

1.2 Motivation

After two updates of the CORINE Land Cover (CLC) data set for the reference years 2000 and 2006 (expected to be accomplished by the end of 2009) the concept of the DLM-DE and the derivation of CLC-data is to be put into practice. Over the years the number of CLC-users has grown and the applications of the data have been broadened from a pan-European and national states scale down to regional scales and to various thematic fields. Along with this development, geoinformation users now require a higher spatial and temporal resolution of consistent European land cover data than conventional CLC-data can offer.

The main task of the BKG is to supply German federal authorities with a wide range of geoinformation like topographic maps, digital landscape models, digital terrain models, orthophotos etc. To satisfy both the national reporting commitment to the EU and the increasing user requirements regarding land cover information the BKG has developed the new concept of the DLM-DE. It covers various needs and concerns of the German federal authorities such as environmental monitoring, spatial planning, security among others. Thereby the Basis-DLM of the Authoritative Topographic-Cartographic Information System (ATKIS) shall serve as the main source vector data set and is enriched by a component of information on land cover according to the current nomenclature of CLC. In the following the wording "DLM-DE" is used in the sense of the land cover component, though the entire DLM-DE will contain the complete Basis-DLM and the land cover component. The overall purpose of this project is a derivation of CLC-data sets of high resolution as well as CLC-data with the conventional MMU of 25 ha from the DLM-DE. An important aspect is the possibility to do so in a cost efficient way by using already existing data like the ATKIS Basis-DLM.

1.3 Data Description

While comparing the two mentioned data sets of CLC and ATKIS, it appears that the ATKIS data model with its high spatial resolution and higher number of feature types has more general definitions and focuses on land use. On the other hand the CLC-nomenclature with a lower spatial resolution but more precise definitions of classes focuses on land cover.

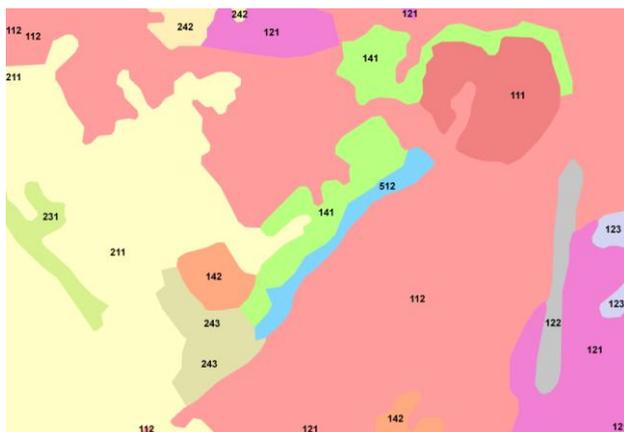


Figure 1. CLC2000, City of Münster (Westfalen), Germany, vector data with CLC-class codes

1.3.1 CORINE Land Cover: The well known CLC-data set has vector format, the conventional EEA-method basically represents mapping of land cover change by visual interpretation of mid-resolved satellite imagery (30x30 - 20x20 m) (LANDSAT 7, SPOT 4/5, IRS Liss III) and comparison with the preliminary imagery and dataset of CLC. The data model was set up to be used in the scale of 1:100.000. Its minimum mapping unit (MMU) is 25 ha for the capture of a new polygon and 5 ha for changes on already existing polygons (Figure 1). The data structure is flat, meaning that the polygons cover 100 percent of the area without any overlaps. The Land Cover classes (three digits codes) are distinguished by attribution of the features (Bossard et al., 2000; Büttner et al., 2006).

1.3.2 ATKIS: The ATKIS Basis-DLM (AdV, 2003a; AdV 2003b) is the basic digital landscape model with a scale between 1:10.000 and 1:25.000, from which all other smaller scaled landscape models are derived (Figure 2). The responsibility of the continuous update lies with the Regional Survey Authorities (Landesvermessungsämter), who deliver the data continuously to the BKG. The data model of the Basis-DLM consists of point (*_P), line (*_L) and polygon (*_F) feature types and is thematically categorised into layers, such as built-up areas (e.g. *SIE02_F*, *SIE03_F*), vegetation (e.g. *VEG01_F*, *VEG02_F*) etc. These layers again contain various feature types (e.g. *2112 industrial and commercial sites*, *4102 grassland*) which are differentiated by attributes. In some cases – depending on the given situation – the data model allows geometry overlapping of multiple layers, which means that one single landscape element is mapped by two or more feature types out of two or more ATKIS layers. For some situations the ATKIS FC even demands overlap of covering layers over ground layers. The MMU of the Basis-DLM is depending on the feature type 0.1 ha to 1 ha, the main source of information is aerial photography with a resolution of 20x20 cm or 40x40 cm supported by ground truthing through the land Survey Authorities.

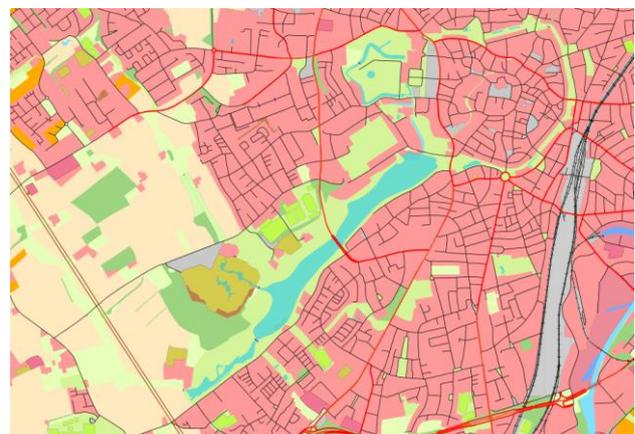


Figure 2. DLM-DE2006, City of Münster (Westfalen), Germany, incl. ATKIS traffic line features (roads and railroads)

2. CONCEPT OF DLM-DE

The concept of the DLM-DE embodies the integration of topographic reference data with thematic remote sensing data. The main application of the DLM-DE is to be capable of deriving land cover information like CLC-data easily and cost efficiently. This can be achieved by using already existing data, namely the ATKIS Basis-DLM. The advantage of the Basis-DLM is that it first already contains a lot of information on land cover in the attribution of the features and second has vector format like CLC does. For the DLM-DE update only the polygon layers of the categories built-up areas, vegetation, traffic and water areas are used because of their relevance for land use/land cover (LU/LC) modelling.

The remaining polygon layers like all line and point layers are not included in the update process of the DLM-DE but are only used as additional auxiliary information. Afterwards these layers are added without being changed or updated to the entire form of the DLM-DE.

Multitemporal satellite imagery with a spatial ground resolution better than 10 x 10 m covering the visible and infrared spectrum shall serve as the main source of information for the geometric and thematic update and verification of the DLM-DE.

2.1 Semantic Transformation

First of all both nomenclatures of ATKIS and CLC have to be compared to find analogies and to identify differences in the definitions of the Basis-DLM FC and the CLC-nomenclature. Hereby both the feature types themselves and their further description through more detailed attribution in the attribute table are taken into account. If necessary new feature types or attributes are created due to missing analogies to CLC-classes in the ATKIS FC. The result is a semantic transformation look-up table (LUT), where every ATKIS feature type is matched to the single or multiple corresponding CLC-class(es), if the semantic transformation is unique or more CLC-classes must be taken into account respectively. If a transformation of the ATKIS feature to one single or a selection of CLC-classes is not possible (e.g. 2332 *Memorial Site*), the feature type is marked as CLC-code “depends on context in the imagery”. The unique CLC-coding of these DLM-DE features must be solved later during the update and verification process according to the satellite imagery.

According to this LUT (see Table 1) and before the DLM-DE verification and update process is started, every feature is enriched by a preliminary CLC-Code (single, multiple or

context-depending) which is stored in an appended column “CLC_BKG” in the attribute tables of the polygon layers.

Because of different data acquisition specifications, definitions of ATKIS feature types and CLC-classes respectively, in combination of varying MMUs, some CLC-classes cannot be derived directly from the DLM-DE, because the ATKIS definitions include a broader range of features in opposition to the relatively precise definition of the CLC-classes. For this reason the following CLC-classes must be integrated in the DLM-DE specification:

- 133 *Construction sites*
- 242 *Complex cultivation patterns*
- 243 *Agriculture with significant areas of natural vegetation*
- 321 *Natural grasslands*
- 324 *Transitional woodland-shrub*
- 333 *Sparsely vegetated areas*
- 421 *Salt marshes*
- 521 *Coastal lagoons*
- 522 *Estuaries*

For the forest classes 311 Broad-leaved Forest, 312 Coniferous Forest and 313 Mixed Forest the definitions vary in the canopy cover or in the height of trees.

2.2 Flat Data Structure of the Basis-DLM

As mentioned above the Basis-DLM FC allows combinations of overlapping geometries, in some cases it even demands them. For reasons of a more efficient workflow during the DLM-DE update, the redundant representation of overlapping features in the data set are eliminated. According to a certain hierarchically ordered sequence the geometries of all CLC-relevant polygon feature types are arranged in a way that the most relevant geometry dominates the other underlying polygons. The result is a singular layer “BDLM_flat” free of overlaps, which serves as the main working data set during the DLM-DE update. Also an overlap information layer is created to indicate the original status of the Basis-DLM and to make the flattening process reconstructable. It contains information about the former overlapping of certain feature types, or just parts of them, and to which thematic ATKIS layer they belong.

2.3 Feasibility study DLM-DE2006

To estimate the expenses and technical feasibility of a nationwide update of DLM-DE, the BKG commissioned the German Remote Sensing Data Center (DFD) at the German Aerospace Agency (DLR) to make a feasibility study according to the BKGs requirements. As test areas four tiles in size of a

| ATKIS Basis-DLM | | | | | CLC | |
|-------------------------|-------------------------------|-----------------------|------------------------|--------------------------|-------------------|-------------------------------|
| <i>Object Type Code</i> | <i>Object Type Name</i> | <i>Attribute Name</i> | <i>Attribute Value</i> | <i>Value Description</i> | <i>Class Code</i> | <i>Class Name</i> |
| 2111 | Housing area | Housing structure | 1000 | Open housing | 112 | Discontinuous urban fabric |
| | | | 9997 | Dense housing | 111 | Continuous urban fabric |
| 2112 | Industrial & Commercial Sites | | | | 121 | Industrial & commercial units |
| 4102 | Grassland | | | | 231 | Pastures |
| | | | | | 321 | Natural grassland |
| | | | | | 421 | Salt marshes |
| 2332 | Memorial Site | | | | 998 | Depends on image context |
| ... | ... | | | | ... | ... |

Table 1. Simplified extraction of the semantic transformation LUT from the ATKIS FC to the CLC nomenclature

topographic map sheet 1:100.000, namely *c1922 Rendsburg*, *c5146 Dresden*, *c6714 Mannheim* and *c8322 Friedrichshafen* were selected.

As a main result of the study the feasibility of the intended project was affirmed. The outcomes of the study are included in the on-going planning process. One result amongst others was the idea of flattening the vector data of the Basis-DLM before starting the update and verification process.

2.4 Implementation for 2009

According to the Transformation-LUT the preliminary CLC-Coding (“CLC_BKG”) attached to the BDLM_flat is verified and updated under the terms of the CLC-nomenclature through mainly visual interpretation of satellite imagery, supported by semi-automated classification. The reference year for the acquisition of the satellite imagery is 2009. The MMU during the DLM-DE2009 update is 1 ha, meaning that every feature of the BDLM_flat smaller than 1 ha will not be updated but only generalised to its neighbouring features. The process of quality controlling shall comprise the usage of a knowledge based interactive tool called “Wipka” developed by the IPI Hannover for the BKG which helps to verify the interpretation of satellite imagery in checking on the most frequent land cover classes like forest area, grassland and arable land.



Figure 3. DLM-DE2006/CLC HR (with CLC-colour legend) under CLC2000 (black bordered, hollow polygons with CLC-class codes)

2.5 Generalisation

From the updated and verified DLM-DE2009 with 1 ha MMU a so called CLC2009 “high resolution” (CLC2009 HR) data set can be derived. It shall be then semi-automatically generalised to the conventional MMU of 25 ha resulting in a CLC2009 “low resolution” (CLC2009 LR). Neighbouring features with the same CLC-coding are dissolved to one single polygon. For the subsequent generalisation a similarity matrix which describes the relation between the CLC-classes in combination with a weighting of the neighbouring feature with the longest common border or the biggest area functions as guidelines for the generalisation process. The BKG is currently working on such algorithms together with the Institute for Cartography and Geoinformatics (IKG) Hannover.

3. OPEN ITEMS

3.1 Pseudo Changes

Due to the transition from the conventional EEA method to the new DLM-DE method some “pseudo changes” in land cover must be factored in while calculating statistics on land cover change. A comparison of both results of conventional CLC2000 and DLM-DE2006 (four test tiles form the feasibility study) will help to quantify the divergence of geometry outlines and to lower the statistical effect of pseudo changes.

There are two different types of pseudo changes which can occur between the polygons of CLC and the DLM-DE vector data set. One are geometric differences, second are semantic/thematic differences due to formerly visual (miss-) interpretation (CLC) versus recently more accurate measurement and attribution (ATKIS).

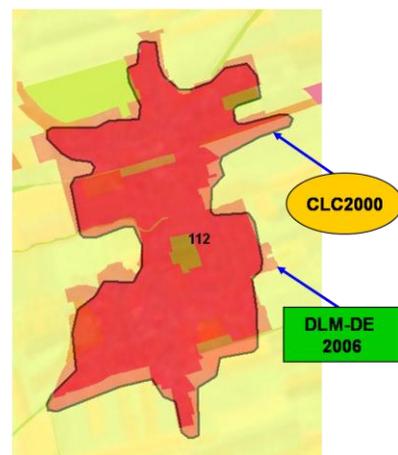


Figure 4. Geometric „Pseudo Change“ of Built-up Area between CLC2000 and DLM-DE2006 from test-tile of feasibility study.

3.2 Generalisation of mixed CLC-classes 242 and 243

Some CLC classes have no analogy in the DLM-DE object type catalogue as mentioned under chapter 2.1 Semantic Transformation. One further open item during the process of the generalisation of the DLM-DE (CLC HR) to CLC LR is the automated generation of the mixed CLC-classes 242 *Complex Cultivation Patterns* (see

Figure 5) and 243 *Land principally occupied by agriculture, with significant areas of natural vegetation*. These are ‘aggregated’ CLC classes, which were designed to map areas of small partitioned agricultural parcels due to the relatively rough MMU (25 ha). In the ATKIS model with a finer MMU (1 ha) such feature types like arable land, grassland, pasture, meadow with fruit trees, fruit and berry plantation, vineyard and orchard are mapped separately in different object types. In regions where many of these land cover types are at close quarters in CLC they are aggregated into class 242 or 243, if the single polygons are smaller than 25 ha. To form these complex CLC classes out of the DLM-DE automatically it is necessary to generate suitable rules.



Figure 5. Example of CLC class 242 Complex Cultivation Patterns (year 2000, hollow polygon, black bordered) not existing in the DLM-DE model (year 2006, coloured areas)

3.3 Separator polygons for generalisation

After the update and during the generalisation process from the the CLC HR to the CLC LR data set all neighbouring DLM-DE polygons with the same or very similar CLC-coding are aggregated together if they reach the generalisation MMU (25 ha). Hereby an unwanted “separator” effect occurs: Some small and often narrow DLM-DE features divide other polygons or groups of polygons with the same or very similar CLC-coding from another (see Figure 6). Because they have no direct contact, both polygon groups are eliminated, the rural settlement disappears from the data set. An open item is to create rules to avoid the unwanted disappearance of important features during the generalisation.

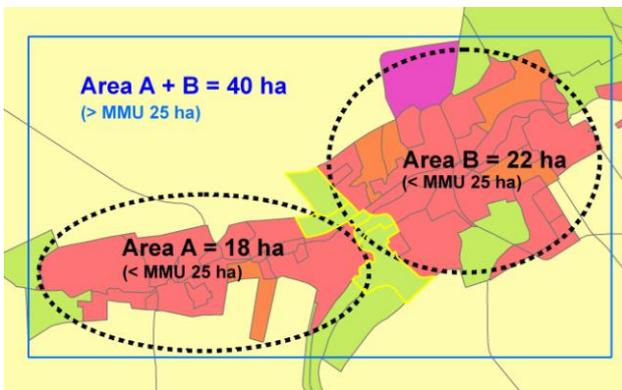


Figure 6. “Separator polygons” for generalisation (green area, yellow outlined): Two groups of DLM-DE built-up area polygons (Area A and B) with similar CLC-coding, each of them smaller than the MMU but together big enough, would be eliminated during the generalisation.

4. CONCLUSION AND PERSPECTIVES

For the digital mapping of land cover information with a higher spatial resolution and a higher geometric and thematic accuracy the DLM-DE as a result of the integration of topographic reference data in the form of the ATKIS Basis-DLM with remote sensing data suits the requirements of the intent.

Costs can be reduced by using already existing vector data more efficiently. Concerning the interoperability between national and pan-European data on land cover information the DLM-DE can be seen as first nation-wide coordinated effort to be prepared for the requirements of the Annex II themes of the INSPIRE directive, where land cover is listed among others.

The Working Committee of the Federal States’ Surveying Authorities (AdV) is about to consider the integration of CLC-conform attributions of spatial features for the future in their mapping activities. Corresponding discussions whether to proceed in that direction are going on. The deriving of European land cover data like CLC will then be even more efficient, accurate and cost-saving.

At present the Regional Surveying Authorities implement a migration from the previous layer structured ATKIS data model to the new AAA-model. It integrates the topographic information, the real estate cadastre (ALKIS) and the official control point information (AFIS). Regarding the ATKIS-part of the AAA-model the nomenclature is restructured and most of the overlapping geometries are eliminated. For future DLM-DE productions (e.g. 2012) the basis for the semantic transformation from ATKIS to CLC will be the AAA-model using an adapted look-up table, after migrating the recent layer-based ATKIS data model to the AAA-model (AdV, 2008a).

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