

VALENTINA SAGRIS

Land Parcel Identification System
conceptual model: development
of geoinfo community
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LIST OF PUBLICATIONS INCLUDED IN THE THESIS

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2. Inan, H. I., **Sagris, V.**, Devos, W., Milenov P., van Oosterom P. and Zevenbergen J. (2010). Data Model for the Collaboration between Land Administration Systems and Agricultural Land Parcel Identification Systems, *Journal of Environmental Management*, Elsevier, 91 (2010) pp. 2440–2454.
3. **Sagris, V.**, Milenov, P., Wojda, P. and Devos, W. The harmonised data model for assessing land parcel identification systems compliance with requirements of direct aid and agri-environmental schemes of the CAP. *Journal of Environmental Management*, 118 (2013) 40–48, Elsevier.
4. Wiemann. S., Bernard, L., Wojda, P., Milenov, P., **Sagris, V.**, Devos, W. (2012). Web Services for Spatial Data Exchange, Schema Transformation and Validation as a Prototypical Implementation for the LPIS Quality Assurance. *International Journal of Spatial Data Infrastructures Research*, Vol.7, 66–87.
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Author's contribution

- Paper 1.** Collection of data for modeling (50%), the LCM model development (90%), paper writing (90%)
- Paper 2.** Participation in discussion on collaboration between two models (20%), model development (40%), paper writing (50%).
- Paper 3.** Collection of the data for new version of the LCM model (35%), development of the new model version (100%), development of the test and pilot testing (100%), paper writing (90%).
- Paper 4.** Collection and preparation of data for test bed (50%), the LCM mapping (40%), paper writing (10%)
- Paper 5.** Collection and preparation of data (5%), the LCM extension for environmental issues (100%), paper writing (80%).

ABSTRACT

This dissertation presents the development of the **L**and Parcel Identification System (LPIS) **C**onceptual **M**odel (LCM) for the administration and control of agricultural subsidies of the European Common Agricultural Policy (CAP).

The subsidies which European farmers receive in the frame of the CAP are administered through the Integrated Administration and Control System (IACS) that are established and run by the EU member states. IACS includes a Land Parcel Identification System (LPIS) as its spatial component. The requirement to map and record land eligible for payments has led to the situation where the agricultural sector has acquired a large amount of geographic data; the geospatial community of data producers, custodians and users has grown during the last decades. The need to assess the quality and consistency of the LPIS towards the EU regulators as well as to ensure systems' interoperability as it is required for compliance with environmental legislation, call for harmonisation efforts. In the view of this, an LPIS Conceptual Model (LCM) was developed. The objective of the study was to introduce the modeling framework of ISO 19100 series for advance of quality of geospatial data in the LPIS domain and of interoperability with other geospatial domains.

The LCM was generated by means of both (i) methodological approaches of International Standards of ISO 19100 series, further extended by the INSPIRE principles, and (ii) reverse engineering of existing operational LPIS systems. The latter is based on the results of two LPIS surveys covering different national implementations. Business analysis of the relevant EU regulations and the LPIS surveys led to the first-cut LCM (Paper 1). Model's core classes cover process of land registration for administration of agricultural subsidies, agri-environmental measures of rural development and environmental restriction. Agricultural and reference parcels of the model build the framework for recording land cover and land use. Further refinement of the model and the quality aspects of the geographical databases are addressed in two studies presented by Paper 3 and Paper 4: the LCM became naturally a part of the LPIS Quality Assurance programme between the European Commission and EU countries. The LCM was used (i) for conformance assessment of national systems and (ii) for implementation of the LPIS Test Bed portal: set of OGC compliant Web services allowing for agricultural data transformation from national data schemas to the common model as well as transferring, checking and storing spatial and non-spatial observations from the quality inspection.

The interoperability with cadastral domain is tested by Paper 2, which is looking for possibilities of the collaboration of two models – the LCM and the Land Administration Domain Model (became ISO19152 LADM). Owner's rights, restrictions and responsibilities arising from land ownership in the cadastral domain have many similarities, but also differences with agricultural practice. The collaboration model established via newly introduced spatial class, also the semantic similarity of administrative classes of both models were analysed in details. Further studies (Paper 5) include a representation of

different European agricultural systems in LPIS and potentials of using LPIS data in the environmental impact assessment of the agricultural policy. Paper 3 proposes different types of land parcel and ways of integration with data from environmental domain viewed in context of the development of agri-environmental indicators (Paper 5).

Developed firstly for the needs of LPIS Quality Assurance Framework of the European Commission, the LCM also became a part of the International Standard ISO19152 – Land Administration Domain Model (Annex H: use case in agriculture) and INSPIRE DS2.8 Land Cover specification (Annex B2: use case in agriculture).

Key words:

Conceptual models, modeling, model conformance testing, data quality, standardisation, Common Agricultural Policy (CAP), Land Parcel Identification System (LPIS), LPIS Conceptual Model (LCM), Agri-environmental indicators

Abbreviations:

| | |
|---------|--|
| AEM | Agri-Environmental Measures |
| ATS | Abstract Test Suite |
| CAP | Common Agricultural Policy |
| CC | Cross Compliance |
| EEA | European Environmental agency |
| ETS | Executable Test Suite |
| FAO | Food and Agriculture Organisation |
| GAEC | Good Agricultural and Environmental Conditions |
| GIS | Geographic Information System |
| IACS | Integrated Administrative and Control System |
| INSPIRE | Infrastructure for Spatial Information in the European Community |
| ISO | International Standard Organisation |
| LAS | Land Administration System |
| LADM | Land Administration Domain Model |
| LCCS | Land Cover Classification System |
| LCM | LPIS Conceptual Model |
| LFA | Less Favoured Areas |
| LPIS | Land Parcel Identification System |
| OGC | OpenGIS Consortium |
| QAF | Quality Assurance Framework |
| SAPS | Single Area Payment Scheme |
| SDI | Spatial Data Infrastructure |
| SDIC | Spatial Data Interest Community |
| SMR | Statutory Management Requirements |
| SPS | Single Payment Scheme |
| SAPS | Single Area Payment Scheme |
| UML | Unified Modeling Language |
| VHR | Very High Resolution (satellite or aerial imagery) |

I. INTRODUCTION

Since its creation in the 1950's the Common Agricultural Policy (CAP) of the European Union (EU) has constantly evolved to reflect the changing needs of both agriculture and society as a whole. At the beginning, the CAP main goals were a stable supply of affordable food and a viable agricultural sector. Nowadays, the direction of the CAP reflects new challenges: to make European agriculture competitive in the world market, to restructure the agricultural sector with respect to very strict standards on environment, food safety and animal welfare (also known as cross-compliance), and to support sustainable and dynamic rural economy. In total, European citizens pay over 55 billion Euro each year for this ambition, which constitutes over 40% of the EU budget. In the last two decades the CAP has been reformed several times, with the aim of better targeting new challenges and better controlling expenditures. The most radical change was introduced in 1992, and from then on the CAP focused on direct income support to the farmers based on cultivated area instead of production. After the CAP reform in 2003, in order to distribute the EU subsidies, each member state established an Integrated Administration and Control System (IACS), including a Land Parcel Identification System (LPIS) as the spatial component of IACS. The main functions of the LPIS are localisation, identification and quantification of the agricultural land via very detailed geospatial data. Furthermore, in order to be eligible for EU support farmers have to adhere to environmentally friendly land management requirements, commonly known as cross-compliance (CC) principles. Farmers can also carry out additional actions to reduce agricultural pressure on the environment or to improve the countryside biodiversity. These are known as agri-environmental measures (AEM) and incur additional monetary support. In the current debate for reforming the CAP post-2013 the above structure seems to be confirmed, with environmental integration to be reinforced. Therefore, management of information on environmentally compliant land use and agri-environmental measures is the second most important function of IACS/LPIS. As a result, nowadays we have considerable amount of geographic data, which is used for the management of the EU agricultural policy and the European-wide geospatial community of data providers and custodians (MARS, 2007; MARS, 2008; MARS, 2009; MARS, 2010; Krugh, 2000).

The LPIS as a concept was developed in 1992 (Council Reg. 3508/1992), when the need of having a system for identification of the agriculture parcels to support IACS, emerged. At that time the data model was purely alphanumeric without any geospatial reference. It was in the Council Reg. 1593 from 2000, where the GIS-based LPIS was promoted. EU member states were given five years to establish LPIS in digital and georeferenced format. Thus, the first year of operational GIS-based LPIS was 2005. At present the users of the LPIS do not consider it as only a supporting tool for the IACS. In fact, the LPIS is becoming a Land Management Information System, integrating information from (and providing data to) many domains. It is already evident that the LPIS

could be the basic source for NSDI in the EU, if proper tools for harmonisation and standardisation on European level are created.

Although the regulatory requirements are uniform across the sector, the particular implementations were subject to member states subsidiarity. Some of the member states used their cadastral data as the starting point for the creation of the new LPIS registers, while others made use of a dedicated production block (farmer's block, physical block or topographic block) system (Milenov and Kay, 2006; Paper 1). Therefore, different LPIS in different member states greatly differ in concepts, models of representation and spatial identification of the agricultural land (Sagris and Devos, 2008a; Sagris and Devos 2008b). These days the main concern of the geospatial community and the European Commission is how well established systems are 'fit-for-purpose', raising questions about the conformity of the systems to European regulations and the quality of the datasets themselves.

Rural areas cover 95% of Europe territory, of which almost half is farmed. This fact alone highlights the importance of farming for the European land resource management. Over the centuries farming has contributed to creating and maintaining a variety of valuable semi-natural habitats, but on the other hand it is one of the main anthropogenic pressures on the rural environment. The cross-compliance principle of the CAP is an instrument to reinforce sound sustainable land management. It calls for special practices on the land, often imposing several restrictions and obligations on farmers. Agri-environmental commitments further encourage farmers to provide environmental services that go beyond following good agricultural practice and legal standards. Not all, but many of cross-compliance measures are related to some location or area. For that reason, separate spatial layers are needed in the LPIS in order to define their geographic extent. The datasets for cross-compliance are primarily collected and maintained outside agricultural information systems by environmental or planning authorities of the member states and, therefore, the different systems need to be interoperable. The majority of the spatial data in question are subject to the process of pan-European standardisation and harmonisation, triggered by the INSPIRE Directive (INSPIRE, 2007). The domain of land administration has undergone a similar process of geospatial standardisation (van Oosterom et al., 2006), which culminated with adoption of the ISO19152 standard in 2012.

Therefore, there is a need to assess the quality and consistency of the LPIS as well as to ensure systems' interoperability with nearby domains such as environmental and land administration. Within this in mind, an LPIS Conceptual Model (LCM) is presented in this thesis. The LPIS Conceptual Model (LCM) was developed in the Joint Research Centre of the European Commission as part of the LPIS Quality Assurance framework¹.

The study had objectives:

¹ http://marswiki.jrc.ec.europa.eu/wikicap/index.php/Main_Page

- (i) to introduce the framework of conceptual modeling of International Standards of family ISO 19100 and methodological approaches for standardisation into the agricultural sector domain;
- (ii) to bring in the concepts of GI quality elements and quality assurance in the assessment of the compliance of the LPIS systems with the EU regulations; to develop efficient, transparent procedures for conformance testing;
- (iii) to investigate possibilities of using of the Spatial Data Infrastructure (SDI) based approach and OGC compliant web services in order to facilitate quality assurance procedures;
- (iv) to study the evidence of a new kind of land management in the agricultural sector, its commonality with and differences between the classical land administration (cadastral) domain; to study the possibility of collaboration between the LCM and informational model for land administration;
- (v) to investigate the interoperability issues with environmental data from different domains such as INSPIRE Annexes themes and investigate potentials of LPIS data use for harmonized environmental impact assessment in agriculture sector.

The methodological challenge of this paper is to combine different pieces of contemporary geoinfo research, which have been developed recently, but at a different pace and in different 'depth'. The International Standards, GIS technology and Web services, principles of geoinfo interoperability are all under continuous development as they are directly influenced by the information technology advances and in particular, more powerful network services, based on open source and proprietary solutions, allowing data transformation and processing to become more accessible.

Next section of this thesis reviews the theoretical backgrounds for the study, state-of-the-art in the conceptual modeling and conformance testing issues. The third section describes in detail the input to the model: main concepts for subsidies administration laid out in the regulations, their spatial aspects and how they were interpreted in practise in the LPIS implementations by member states administrations. The fourth section is dedicated to the results: the LCM, its development process and the most recent version. This section highlights the interoperability issues with environmental (sub-section 4.3) and land administration domains (sub-section 4.4). Subsections also present how the LCM can be used for the conformity and quality checks of the existing implemented system: the Abstract Test Suite for mapping between the LCM and existing systems that was developed and tested in collaboration with several member states. Finally, the discussion section investigates the experience in the model and test suite development and further possible ways and applications for the LCM.

2. THEORETICAL FRAMEWORK AND METHODOLOGY

2.1. Conceptual modeling

When people view their surroundings, they simplify the inherent complicity of the environment by abstracting key features to create a ‘model’ of what is observed. This cognitive process is influenced by cultural, occupational and educational background of the viewer as well as by the purpose of the observation study. In geoinformatics, the process of simplification of the geographic phenomena or system is called geospatial modeling and has as its purpose the production of geographical data that may be used in graphic and digital form for phenomena description, representation and analysis (Bolstard 2006; Laurini and Thompson 1994.; Clarke 1990; Burrough and McDonnell 1998). Textbooks specify several levels of abstraction: reality model, conceptual model, spatial data model, representational model, physical (computer) model.

Geographical phenomenon requires two types of descriptor to represent the real world: *what* is present and *where* it is located. For the first question, concepts as ‘road’, ‘river’, ‘town’ etc. act as fundamental building blocks of information (Burrough and McDonnell, 1998) used by people to perceive, classify and communicate information about real world features they operate with. When information about large application field or complex domain needs to be collected and exchanged, the formalisation of the conceptual model becomes necessary in order to ensure that data is interpreted without ambiguity and communicated efficiently. In order to answer the second type of questions, like ‘*where?*’ phenomenon is, ‘*what shape?*’ and ‘*what extend?*’ does it have – in other words to express geographical aspects of the phenomenon – models of referencing in geographical space (coordinate reference systems) as well as geographical data models as a set of geometric constructs (e.g. points, lines and surfaces) shall be used. These geometric constructs provide concepts on how is space discretized into parts for features’ unique identification, localisation, measurement and spatial analysis (Burrough and McDonnell, 1998).

By its nature, the conceptual modeling as a discipline belongs to informational systems analysis and design and constitutes informational part of the geographic information system (GIS). Conceptual models are used to define user requirements and as a basis for developing information systems for enterprises and state agencies handling large amounts of geospatial information. They can be used to support the development, acquisition, adaptation, standardisation and integration of information systems (Wand and Weber, 2004; Moody, 2005). Some authors stay that conceptual models are design artefacts used to actively *construct* the world rather than simply describe it (Moody and Shanks, 2003).

The current basis of geospatial data conceptualization has been worked out by organizations such as the Open GIS Consortium Inc. (OGC), Technical Committee 211 of International Organisation for Standardisation (ISO/TC 211),

governmental organizations, the geographic information industry and the geographic information academic community. Considerable progress has been made with regard to content and structure of geometric data as well as with syntactical description of geospatial data (Egenhofer, 1999; Brodeur, Bedard and Moulin, 2005). These efforts are consolidated in geoinformation standard documents such as ISO19100 series standards published by TC211, Open GIS Consortium Inc., (OGC, 1999 and 2001). However, to enable complete interoperability of geospatial data, it is essential to go beyond structural and syntactic heterogeneities and to address semantic (thematic) heterogeneities as it is done for geometric and temporal heterogeneities (Brodeur *et al.*, 2005).

Many science domains generate data and information with a geographic location reference (Yang *et al.*, 2010). These georeferenced or geospatial data have inter-connections that follow geospatial principles/constraints, such as those of geospatial analysis and geospatial modeling (Smith, Longley, and Goodchild, 2007). Geospatial communities of these scientific domains working in particular application field (e.g. hydrology, geology, cadastre etc., for an overview see Yang *et al.*, 2010) are often acting in close collaboration with standardisation bodies. A cross-cutting integration that can support geospatial data processing within and across scientific domains is desirable.

In the cadastral domain, Steudler (2006) describes fifteen years experience of the Swiss cadastral core model called INTERLIS. In the paper of van Oosterom *et al.* (2006) a core cadastral domain model (CCDM) is presented; this model is suitable for cross-country use and enables involved parties, both within a country and between different countries, to communicate based on the shared ontology implied by a common model. The CCDM model further evolved into the Land Administration Domain Model, LADM (submitted by the International Federation of Surveyors (FIG) as new standard to ISO/TC211, 2008) and the Social Tenure Domain Model, STDM (Augustinus *et al.*, 2006). The latter was created as an initiative of UN-HABITAT and is meant specifically for developing countries, countries with very little cadastral coverage, and also for conflict areas and areas with large scale informal settlements.

In contrary, the Agriculture Data Model Project (ESRI, 2003) has provided a data model that is designed to be used at farm level. It constitutes that farmers' spatial operations differ from those of a government agency, or the research of an agricultural scientist. Nash *et al.* (2009) and Sørensen *et al.* (2010) also investigate information flows on the farm level proposing their model for a farm management system. A growing number of publications in modeling of land resources can be found in geological science (e.g. Sen and Duffy, 2005; Lake, 2005; Simons *et al.*, 2006). In the environmental domain, the INSPIRE data specifications (INSPIRE, 2007; INSPIRE DT DS and D2.6, 2008) are examples of common conceptual models for different data application fields agreed by stakeholders at the EU level. The INSPIRE Directive makes provisions for 34 common data specifications covering 'reference' (or general geographic) and thematic environmental data. Several INSPIRE data specifications are relevant to land registration and cross-compliance issues in the CAP, some to mention

are: land cover, land use, cadastral parcel (INSPIRE CP, 2009), orthophoto imagery and protected sites (INSPIRE PS, 2009).

Analysing literature on the topic, one can notice that conceptual domain models are created for different purposes. To start with, they can be used for the generation of a new derived implementation, like establishing land administration systems in developing countries (Hespanha *et al.*, 2008; Augustinus *et al.*, 2006). In countries where spatial data and systems are already well developed, common specifications foster interoperability between data and applications. For regions combining several countries, data harmonisation and standardisation through conceptual models ensure common understanding and co-operation. Therefore, some of the conceptual models are now on their way to become international industry standards, e.g. Land Administration Domain Model (Hespanha *et al.*, 2008), adopted as ISO19152 and Land Cover Classification System which is proposed for ISO19144-2. This thesis introduces the case where the common conceptual model is used for assessing the uniform quality of the agricultural databases across the EU member states.

2.2. International standards' approach to conceptual modeling

ISO 19100 series provide a standardised framework for modeling of geographic information and data representation. As mentioned before, a model is a description of the reality or at least of its part that is related to particular human activity. Any description of reality is always an abstraction, always partial, and always just one of many possible 'views' depending on the application field. The portion of the real world containing all phenomena of interest, their properties and relations constitutes the '*universe of discourse*' (Figure 2.1). While GIS community prefers term 'universe of discourse', IS professionals speak about 'business model' in order to describe actors and business rules for particular human activity field. The modeling process consists of the creation of an abstract description and a set of concepts about the world of interest by means of conceptual formalism. It results in a conceptual model of *spatial objects* or *features*. Both terms – spatial object and spatial feature – are used to describe geographic features, the first one is coming from ISO terminology and the latter is preferred by the INSPIRE community. Spatial features represent concepts of real world phenomena associated with a location relative to the Earth's surface, about which data are collected, maintained, and disseminated (ISO19110). A feature may occur as an *instance* or as a *type*. The feature instance deals with concrete phenomenon, such as 'Danube River', and can be associated with its geographic and temporal coordinates. Similar instances with common characteristics can be classified into *feature type* –e.g 'river'– which may be portrayed in a similar way. Geographic feature types are an instrument for organizing and representing the classification of real world phenomena in a set of geographic data, they act as building blocks for the model.

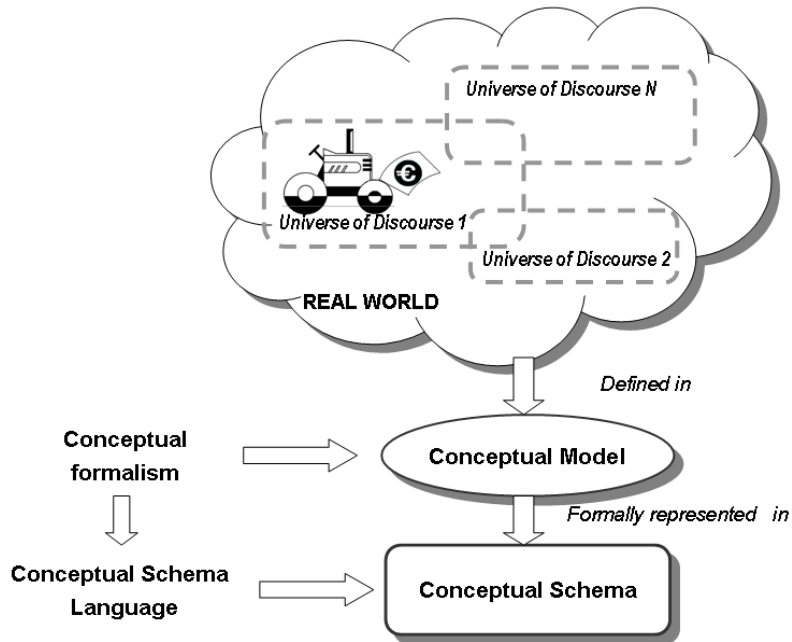


Figure 2.1: From reality to the conceptual schema (adopted after ISO 19101).

The *General Feature Model* described in ISO19109 (GFM) is a meta-model for developing conceptual models of feature types and their properties, i.e. it is a conceptual formalism for geographic information. The GFM defines the concept of feature type, feature attribute, feature association and feature operation. Further, a conceptual model can be described verbally or be documented by means of a conceptual schema language. The rigorous description of a conceptual model for some portion of the real world by means of conceptual schema language is a *conceptual schema* (ISO 19101). Conceptual formalism and conceptual schema language are interrelated. A conceptual schema language is based upon a conceptual formalism. The conceptual formalism provides the rules, constraints, inheritance mechanisms, events, functions, processes and other elements that make up a conceptual schema language. These elements are used to create conceptual schemas that describe a given information system or information technology standard.

The ISO19100 series of standards use the Unified Modeling Language (UML, ISO19103) class diagrams with UML Object Constraint Language (OCL) as the conceptual schema language for specification of the normative parts of the ISO19100 series of standards (ISO19101). Therefore, geoinformation models, which are claimed as conforming to ISO19100, shall use the same UML/OCL for model description. The UML has its own meta-model: classes that act as feature types in conceptual formalism; class attributes, operation and constrains; associations between classes and, finally, packages

which are used for structuring the model into logical parts. Both the GFM and the UML meta-models deal with classification, and thus the concepts are very similar. Still, there is one important difference: the concepts in the General Feature Model establish a basis for the classification of spatial objects, whereas the UML meta-model provides a basis for classification of any kind.

In order to arrive from the real world to the meaningful geographical database, several steps of formalization are required (Figure 2.2). The role of *Use Cases* as a methodological element to capture and identify user requirements should be specially underlined on the way from universe of discourse to geodata. The analysis of Use Cases is intended to identify the information required, to describe the current situation with information available and to analyse the gaps between required and currently used data. *Model of feature types* is a set of feature types and their relationships, which represents the universe of discourse. The definitions of the feature types and their properties, as perceived in context of an application field, shall be derived from the universe of discourse examining all available resources: regulatory requirements, business rules, current practice, similar concepts applied in akin domains.

ISO 19101 distinguishes two formalization representations of the model of feature types and their properties: (i) an application schema (described in ISO19109) and (ii) a feature catalogue (ISO19110). Both representations contain the same information, but they serve for different purposes. An *application schema* is a *conceptual schema* that defines how a universe of discourse shall be described as data and operations. Its purpose is to achieve a common and correct understanding of the data content by making it possible to gain an unambiguous and computer-readable representation. An application schema defines the logical structure of data and may define operations that can be performed on or with the data, specifies the feature types and their properties (attributes, association roles, operations) as well as constraints. It may be purely internal for a certain implementation (either a system or a database) or may be common for two or more implementations. In order to be conforming to the ISO 19100 series of standards an application schema shall be defined in a formal conceptual schema language and shall follow rules laid down by ISO19109 standard for application schema. This ensures automated processing of geographic datasets, e.g. encoding, data access, data transfer, querying and updating.

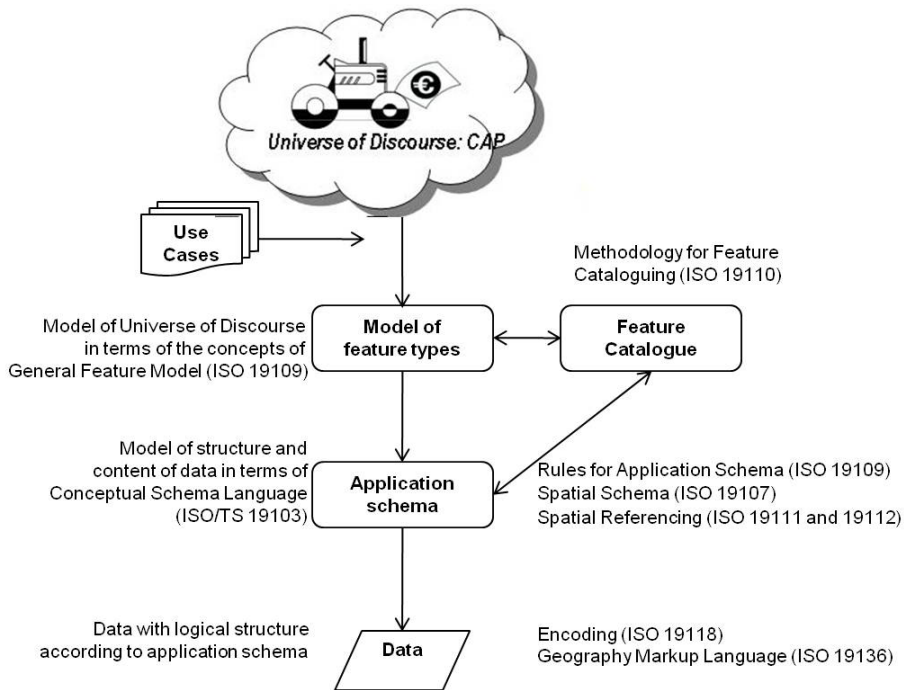


Figure 2.2. A pathway from real world to application data through the application schema (adopted after ISO19109).

An application schema has the following parts:

- the semantic content of the geographic dataset following the concepts and structure defined in the General Feature Model. Concepts that can be mapped to feature types, feature attribute types, feature relationship types and feature operation types;
- a specification of the reference system(s) used to represent position or – the reference system(s) to which position is referenced (ISO19111 – Spatial referencing by coordinates, ISO19112 – Spatial referencing by geographic identifiers);
- the geometry feature types used to represent the spatial aspects of geographical features (obtained from the ISO 19107 – Spatial Schema).

The application schema integrates parts of the other standardised schemas that are necessary to describe the structure and content of a particular dataset. This process is also known as *model integration*. The ISO 19100 standards schemes, sometimes referred to as foundation schemas (INSPIRE D2.5), are integrated into ISO/TC211 Harmonised Model. The most frequently used parts of the ISO/TC211 Harmonised Model include *spatial schema*, *quality schema* and the *reference system schemas*. Other schemas, which are not from the ISO 19100 series, may be added based on thematic requirements during the development

phase, such as application schemas for the different spatial data themes of the INSPIRE Annexes I, II and III (INSPIRE Consolidated Model).

Feature catalogues contain a large subset of the application schema information, but play a slightly different role. A feature catalogue documents the feature types in a textual form, frequently organised and styled as tables. The format of a feature catalogue is the most convenient way of representing schema content for domain experts without experience in information technology; therefore the creation of the feature catalogue is an action where participation of business experts is of crucial importance. The advantages of the feature catalogue are that it can be translated in to many languages and it can be queried for particular, individual elements of the schema.

The ultimate goal of the geospatial modeling process of Figure 2.2 is meaningfully organised geographical *data* (Figure 2.2). The physical structure of the *dataset* is system/software dependent. On the database developing stage systems can import an application schema in order to create an initial, empty dataset, which will be further populated via collection of data about features or via data import/interchange. The data import from one system/format to another is always software specific conversion. In contrast, *data interchange* is the procedure for encoding, delivery, transfer, receipt and interpretation of (geographic) dataset through a system independent format. ISO 19100 series of standards recommend to use an XML with its geographic extension GML as such a format (ISO19136, OGC 2001). Because of its independence, data interchange is a central concept of the geographic data interoperability; the conversion of data from system format into XML/GML code is called *encoding*. Therefore, the key elements of successful data interchange are the knowledge of the content and structure of the data, which is defined by application schema and encoding rules specified by ISO19118 and be used to ensure a consistent conversion to a system independent format.

2.3. Testing of conformance of geoinformation systems

Standards for geographic information define conformance for geographic data as a fulfilment of specific requirements (ISO19105). However, geospatial data cannot be directly tested towards the legislative text, which set the requirements. An additional step, a ‘translation’ of the basic concepts into a conceptual domain model, is necessary. If we want to examine a conformance of the implementation of the CAP regulation on LPIS, we need to establish a conceptual model and then test member state implementations against that model. The structure of the real geographical databases can be described by application models and application schemas. In order to evaluate the conformity of the implemented database, the application schema should be *mapped* against a conceptual schema. In cases when different datasets of different organisations and institutions need to be integrated for any kind of visualisation and analysis, data can be *transformed* in the structure of the conceptual schema using

'mapping' parameters. Therefore, conceptual models and data specifications serve as the basis for conformance testing. These models are subject to an agreement between geoinformation community members, i.e. data providers, custodians and users.

ISO19105 provides two steps of conformance testing. The first step identifies the logical consistency of dataset(s) with the requirements in order to ensure that the basic concepts are represented in an appropriate way by analysing the data specification. The second step examines the datasets themselves for completeness, positional, temporal and thematic accuracy as well as against their own specifications, tested in step 1. It should be mentioned that logical consistency, tested in the first step, is one of the basic data quality elements recognized by ISO19138 and 19113.

As the means for conformance testing, ISO19105 proposes a framework of an **A**bstract **T**est **S**uite (ATS). It is developed for testing geoinformation products and systems against the requirements of ISO/TC 211 family of International Standards. Its development is based on common testing practices in software engineering and graphics/image processing (ISO19105, 2000). Assuming that common data specifications and domain models can be seen as standards for particular geospatial community, we can extend the ATS framework to conformance testing in any domain. The methodology of the ATS foresees the manual comparison of application specifications towards the specification of the standard by using basic and capability tests (section 4.5).

The testing and schema mapping issues are currently in the focus of the geospatial research mainly due to the testing of the INSPIRE Annex I Data Specification (INSPIRE 2008, Lutz, 2009). The methodology includes two methods: (i) manual comparison via templates and/or (ii) the so-called transformation method. First approach is analogical to ISO19105, while transformation testing makes use of software-aided mapping, which can be applied offline or online through the web services. The goal of the testing exercise in 2009, as seen by INSPIRE thematic working groups, was to test and tune the Implementation Rules, data specifications and guidance documents. On the other hand, spatial data communities and data custodians had the possibility to assess how well their datasets are aligned with the INSPIRE data specifications' requirements. Since data custodians are supposed to ensure their datasets transformation into INSPIRE data specification schemas by the 2013 for Annex I themes, the testing of transformed data conformance is a feature issue of the INSPIRE process (M. Lutz, personal communication).

During the abovementioned exercise, the spatial software developers and academia had an opportunity to assess the readiness and demonstrate the usefulness of transformation tools and methods. The recent INSPIRE guideline documents (INSPIRE 2010-a, INSPIRE 2010-b) contain an analysis of the state-of-the-art on schema mapping and transformation issues. According to this analysis, one of the challenges is the lack of a standard meta-language for model mappings. The XSLT – Extensible Stylesheet Language Transformation – can be used to transform XML encoded datasets, but it is reported to have weak

performance when it comes to processing large GML files. There are several commercial and research transformation tools available, using different languages; few to be mentioned are Feature Manipulation Engine (FME) (Safe Software), GoPublisher (Snowflake Software) and Radius Studio (ISpatial). Mapping rules expressed in one software environment cannot be easily used in or imported into another.

2.4. Model background and choice of methodology

The LCM has been developed during my work at the Monitoring of Agriculture Resources (MARS) unit of the Institute for Protection and Security of the Citizen of the European Commission Joint Research Centre (IPSC JRC). The draft version of the LCM was available for discussion among the LPIS geoinformation community from January 2008 and published by Sagris and Devos (2008a and 2008b). At that time the aim of the LCM was the testing of member state implementation conformance towards the legislation. It has been reviewed by the LPIS geospatial community and was modified several times until a first operational version of the LCM became available at the end of 2009 (Sagris and Devos, 2009).

The development of the LCM was greatly influenced by the results of the Abstract Test Suite (ATS) trial in which five member states participated. LCM development continued when first ATS results from all member states became available in May 2011.

The following methodology was applied. First, basic concepts from the EU legislation were extracted and documented. They became the basic, spatial and non-spatial classes of the first-cut UML model. By further analysing the legislation and documentation on existing LPIS implementations obtained from surveys (Milenov and Kay, 2006; Zielinski and Sagris, 2008 and 2009) or member state presentations during LPIS workshops, basic classes were refined with specialisations, attributes, and code lists for the attributes. For environmental issues those concepts that are already modelled in the INSPIRE domain and became a part of the INSPIRE consolidated model, were re-used in the LCM as external classes through integration classes. For testing the ATS was developed and after several iterations and adjustments had been done, the current versions of the LCM and the ATS took their shape. Finally, the UML model was converted into a GML application schema. The modeling work was done using Enterprise Architect (by Sparx Systems) software, whereas ShapeChange software (by interactive instruments GmbH), was used for the UML-GML conversion.

3. INPUT TO THE MODEL

3.1. 'Universe of Discourse': defining the domain for the CAP direct support schemes for farmers

Since the 2003 reform, the CAP has aimed to work towards for a stable farmer's income, decoupled from production, within a framework of sustainable development of the rural areas while respecting environmental and other societal needs (Figure 3.1).

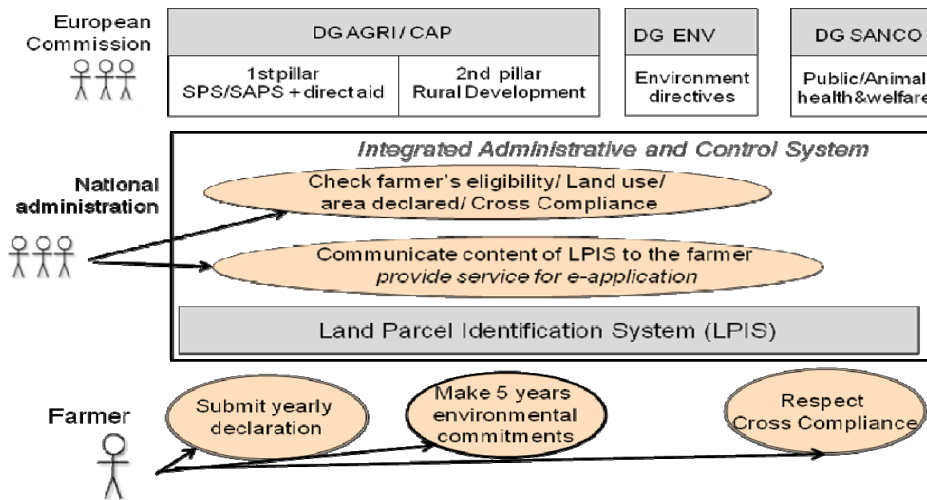


Figure 3.1. Universe of discourse: use case diagram illustrates the CAP Direct payments domain, key stakeholders and the place of the LPIS in the process of subsidies administration.

3.2. Spatial and non-spatial concepts in the CAP regulations

The principles and rules, which govern CAP business processes, are laid down in following legislation documents: Council Regulations 71/2009, 72/2009, 73/2009 and European Commission Regulations 1120/2009, 1121/2009, 1122/2009. Due to the fact that these concepts are very briefly covered in the articles, they are introduced in this section (in *italic*) and Annex I presents the list of concepts as they are defined in the regulations.

The central concept connecting all stakeholders in the domain is the *farmer's single application*. The *farmer* when lodges his yearly application to the *paying agency* shall include (Comm. Reg. 1122/2009): (a) the identity of the farmer; (b) *the payment scheme(s)* concerned; (c) the identification of payment *entitlements*; (d) particulars permitting identification of *agricultural parcels* on

holding and *their area*. For purpose of (d) *farmer's sketch map* of agricultural parcels is used. Agricultural parcels of the application shall be allocated in side of the *reference parcels* of the identification system. Paying agency makes the information on reference parcels available to the farmer at the begging of each application year. (see Figure 4.3 illustrating model of core concepts in the LCM).

Each farmer registered to the system shall activate his entitlements, which give him the right to benefit from one or several EU payment schemes. Entitlements were allotted to farmers actively farming at the date each country introduced the *Single Payment Scheme (SPS)* based on the reference amounts they received previously (amounts of direct payments each farmer received in the three-year period individually or per region). Note that so-called new member states had the option to implement a simplified scheme without entitlements (*Single Area Payment Scheme: SAPS*) where all *eligible hectares* represent the same financial value.

Finally, an *agricultural area* is a concept used to identify land, eligible for payments. It refers to an area taken up by arable land, permanent pasture, permanent crops or others, which are especially mentioned in payment scheme(s) definition. Identification and recording of the agricultural area is the main task of the LPIS. An *agricultural use* stands for the use of an area in terms of the type of *crop* or ground cover or the absence of a crop.

3.3. Concepts for mapping land for subsidies

In view of the abovementioned definitions, there are two basic spatial concepts: (i) agricultural parcel or farmer's field which is a part of aid application, and (ii) reference parcel which is the spatial object in the LPIS and corresponds to the core data layer maintained for purpose of aid administration. The distinctive properties of these two different concepts are illustrated by Figure 3.2.

In addition to being the subject of the payment calculation, agricultural parcel is also a subject of administrative cross-checks and control procedures established in the IACS. However, due to the dynamic nature of agricultural activity, an agricultural parcel can be unstable over time and space (crop rotation, out of use, aggregation or subdivision of fields, different extent of use, conditions for eligibility for payments etc.). Therefore, the regulations set up that for the purpose of identifying the agricultural parcel the reference parcel is used as the basic unit of the LPIS. The relation between these two concepts is established by Art 6(1) of the Comm. Reg. 1122/2009 (see Annex I). The regulation specifies that a reference parcel can be either a cadastral parcel or production block. Reference parcel may contain one or many agricultural parcels declared for aid by farmer(s) and shall have a unique identifier at national (in some countries regional) level. No aid can be claimed outside the reference parcels of the LPIS.

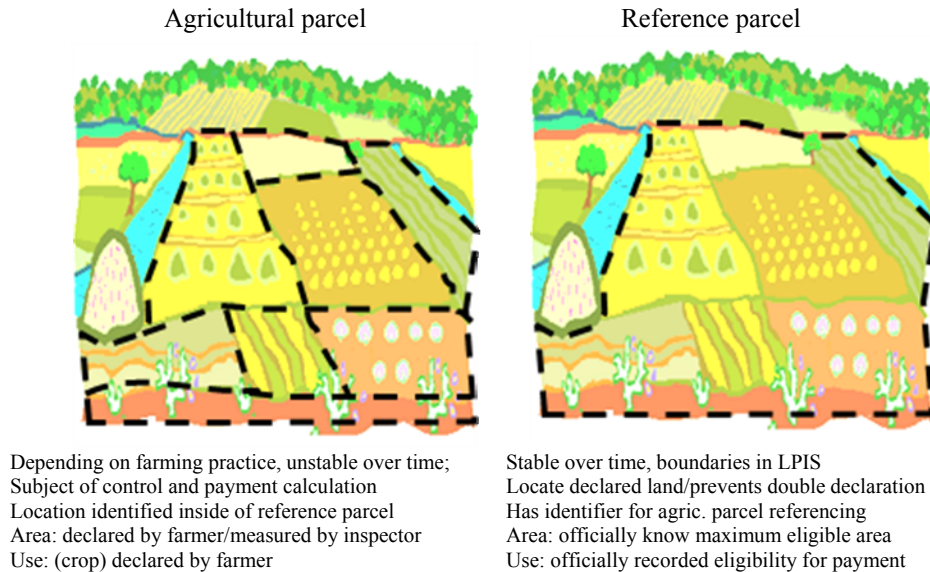


Figure 3.2. Properties of agricultural and reference parcels

Land cover can be unambiguously mapped from orthophoto imagery or field survey and land condition can be explicitly monitored and checked without respect to (intended) use. The use of an area in terms of the type of crop or ground cover or the absence of a crop (Comm. Reg. 1122/2009 Art. 2) constitutes the ‘use’ of agricultural land and is recorded as an agricultural parcel. Furthermore, clear distinguish between land cover and land use in IACS databases make them a unique data source for the development of agri-environmental indicators across Europe (Paper 5).

3.4. Cross-compliance and rural development

Cross-compliance (CC) links the eligibility of payments to the farmer’s fulfilment of Statutory Mandatory Requirements (SMR) and Good Agricultural and Environmental Condition (GAEC) requirements. The EU regulations establish only general areas of cross-compliance, therefore the details of the CC requirements are laid down by every individual country. A full list of SMR that should be taken into consideration in respect to direct payments and references to the regulatory acts establishing them can be found in Annex II of Council Reg. 73/2009. In Annex II they are listed together with geographic components which can support them in the LPIS. Based on the table of Annex II, we can distinguish requirements for three spatial themes for SMRs to be incorporated into the LPIS: *protected areas* of NATURA2000, *nitrate vulnerable zones* and *location of animal farms*. These three may be further supported by data for soil parameters (soil types, organic matter content, infiltration, porosity) and topo-

graphic/hydrological surfaces' parameters such as slope, ground water depth and depth of aquifer. This data originates from different external sources and is usually integrated into the LPIS databases. The full list of GAEC that should be taken in to consideration in respect to direct payments and references to the regulatory acts establishing them can be found in Annex III of Council Reg. 73/2009. In Annex II of this thesis they are listed together with the geographic component they may contain.

Regulatory framework for **Rural Development** support scheme consist of Council Regulation 1698/2005 setting up provisions from 2007–2013 and Comm. Regulations 65/2011 and 679/2011. From all the measures set up by those documents only measures of so-called axes 2 of rural development scheme –‘improving the environment and the countryside’– have a geographic component. Those measures are (1) handicap and mountain areas commonly known as *less favoured areas for agriculture* (LFA) and (2) *areas of agri-environmental measures* (AEM), where farmers take environmental obligations not defined by of cross compliance and (3) *afforestation measures*. LFA data layer is usually created on the basis of an administrative division layer, where each municipality assigned status and type of handicap. This status is usually fixed in the regulative act for rural development. Agri-environmental and afforestation commitments are recorded at reference or agricultural parcel level.

3.5. LPIS questionnaires

Two questionnaires were organized in the framework of the LPIS workshops in 2006 (Milenov and Kay, 2006) and 2008 (Zielinski and Sagris, 2008 and 2009), with a goal to gather information about the status of LPIS systems in the EU. One of the subjects covered was a wide range of reference parcel types in use. Other parts of the questionnaire looked into the use of orthophoto imagery, quality issues, information flow from farmer to administration and *vice versa*. Information was verified and updated during a model conformance testing exercise in 2010 (full report not published yet). There are 43 national and regional LPIS implementations in the EU (2 in Belgium, 4 in United Kingdom; 13 in Germany). From them 27 systems participated in the questionnaire of 2006, 25 participated in 2008 and 20 participated in both. During the 2010 exercise, 42 LPIS implementations submitted model conformance reports (and 23 the same as in 2008). Only 15 countries or regions participated in all three screenings.

4. RESULTS

4.1. Typology of reference parcels

For creating reference parcel registries some of the member states used their cadastral data as the starting point, while others made use of a dedicated production blocks (farmer's block, physical block) system (Milenov and Kay, 2006; Paper 1; Zelinski and Sagris, 2009). All reference parcels can be conventionally classified into four classes (Paper 1, Paper 5), differences between types are shown by figure 4.1 and table 4.1. The most recent version of the LCM (Papers 3, 5) added a fifth type by subdivision of the physical block in two types, introducing the topographic block, which is close to the physical block by its properties (Paper 5). Advantages and disadvantages of each type are discussed in Paper 1 and Paper 5.

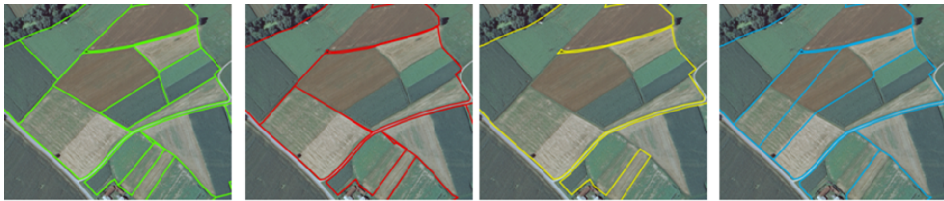


Figure 4.1. a) single field parcel; b) farmer's block; c) physical block; d) cadastral parcel

Table 4.1. Different types of reference parcel and their main properties (Paper 1, Table 1)

| | = Single field parcel | < Farmer block/ilot | < Physical block | Cadastral parcel |
|-------------------------|-----------------------|----------------------------|----------------------------|-----------------------------------|
| land use for aid scheme | one single crop group | one or several crop groups | one or several crop groups | do not match agricultural pattern |
| applicants | single farmer | single farmer | one or several farmers | one or several farmers |
| temporal aspect | annual | multi-annual | semi-permanent | land tenure cycle |
| main data source | farmer's application | farmer's survey | administration survey | land register/cadastre |

The distribution of different reference parcel types across EU in 2010 is shown in Figure 4.2. From 43 LPIS implementations there are only five examples of single crop parcel type – Luxemburg, BE-Flanders, GE-Hessen, GE-Saarland and Malta. Those systems are the most detailed, where each field has explicit geographic location, but that implies re-digitalisation or update of whole database every year, which is a time-consuming and expensive task for bigger countries. Five countries and two regions apply cadastral parcel – Poland,

Spain, Austria, Italy, Cyprus as well as Baden-Württemberg and Rhineland-Palatinate in Germany; this approach implies that cadastral system matches land use /agricultural practice (Paper 2; Inan *et al.*, 2008-a). Latter was not the case in majority of the countries that joined the EU in 2004 and 2007 and where, at the time of LPIS creation, land reforms were an issue. Therefore, systems of blocks are dominant in the CAP land registration – in the EU-15 farmer’s block (if we count by countries only) and in the EU-12 physical block type prevail. The physical block is the loosest mapping, but its advantage is that the database can be created and maintained by responsible institution only on the basis of land cover information from imagery. Therefore, to apply the physical block system was the easiest way to create the initial LPIS from scratch. Farmer’s block type is a tighter allocation of farming activity, but involves interaction between the administration and the farmer to explicitly define the block. This solution is suitable for countries with stable land use patterns based on ownership or tenure (e.g. in France the agricultural land tenure is regulated by the minimum rent contract duration, which is nine years). It is interesting to notice that four of the countries/regions from 20, which answered questionnaires in 2006 and 2008, have changed reference parcel type or rethought/redefined its definitions (Belgium-Wallonia, Ireland, Sweden, and Portugal). From 2006 to 2010 all together 11 countries/regions changed type of reference parcel. Also four countries indicated that they use a mixture of reference types or more than one type.

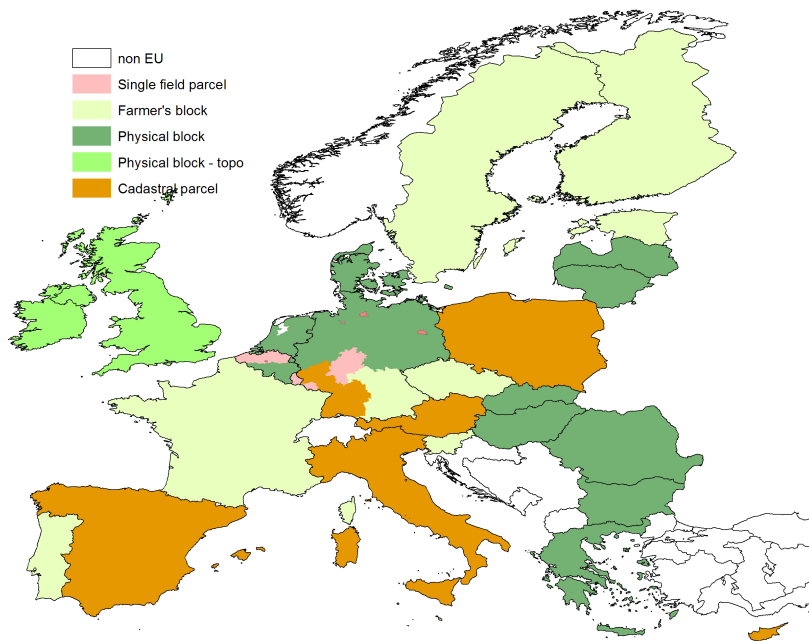


Figure 4.2. Types of the reference parcel in use, from the questionnaire in 2008 and updated after model conformance test in 2010.

4.2. LPIS Conceptual Model (LCM)

4.2.1. Core classes

The core of the LCM consists of classes, which are representing the basic concepts of the universe of discourse CAP direct subsidies (see section 3.1). Figure 4.3 presents the model of the concepts of IACS and Figure 4.4 – core classes of the LCM. The key concept ‘Single Farmer’s Application’ is represented as AidApplication class and related to Farmer and Agricultural parcel classes. Each AgriculturalParcel shall be located inside of one or more reference parcels of the LPIS (1:1), and a ReferenceParcel can contain none, one or several declared Agricultural parcel(s).

Due to their diverse nature, AgriculturalParcel and ReferenceParcel classes have different sets of attributes. The attributes of the AgriculturalParcel reflect the payment administration process, while attributes of the ReferenceParcel contain information on what can potentially be claimed. The central part of the business process is a precise determination of the area to be paid (for definition of determined area see Annex I of the thesis). Given that the payment amount depends directly on that area, there are several attributes concerning the area calculation process. The agriParcelNr is its number in the application form, whereas referenceParcelID indicates the reference parcel where the production unit is located.

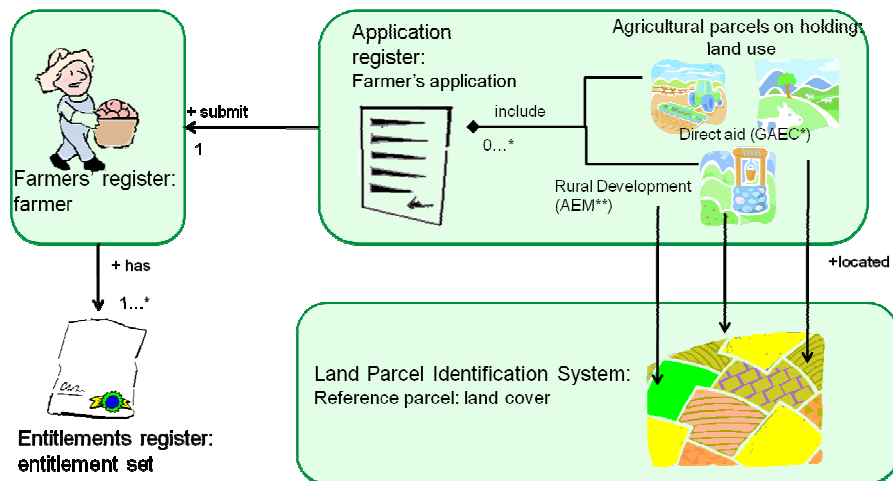


Figure 4.3. Model of concepts of subsidies' administration. *GAEC – good agricultural and environmental conditions, ** AEM – agri-environmental measures

The attribute declaredArea stores the parcel area as estimated by the farmer at the time of application, while determinedArea corresponds to the result of a crosscheck process undertaken by the administration, which establishes the area to be paid, applying a particular paymentType.

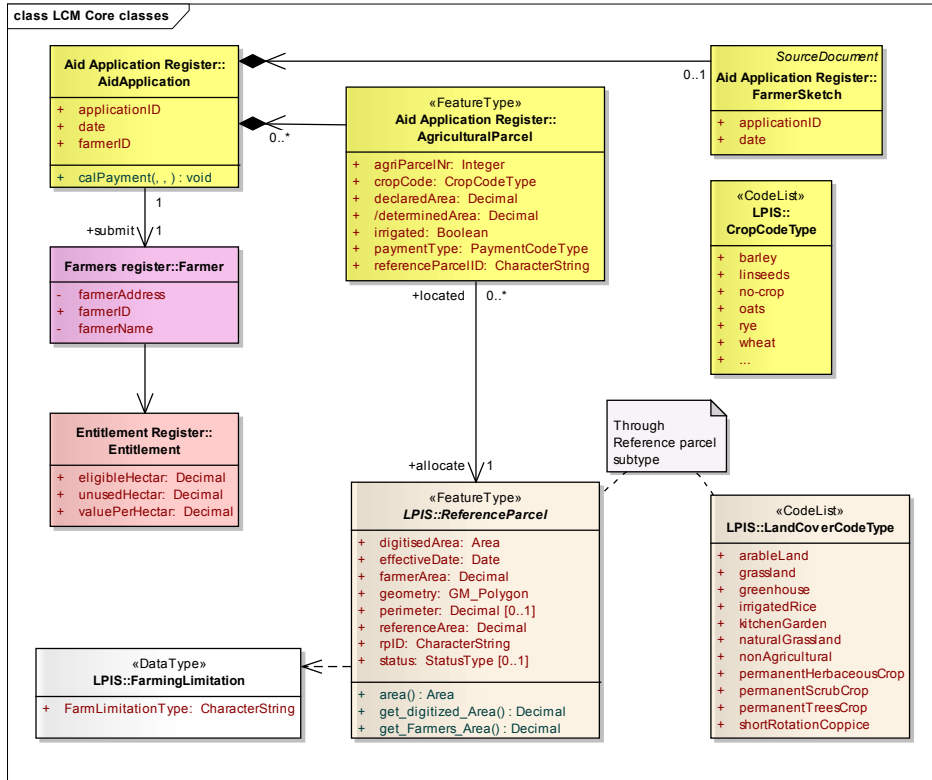


Figure 4.4. Core classes of the LCM.

For **ReferenceParcel** class attributes, digitizedArea and perimeter correspond to the geometry of a spatial object as it is digitised in the LPIS database. However, the precision for reference parcel digitisation is set to 0.1 ha (all non-eligible features bigger than this threshold should be excluded out of the otherwise ‘pure’ eligible land) by the legislation, while precision of the determination of the area for payment is set to 0.01 ha. It means that some very small non-eligible objects can still remain inside the polygon of the reference parcel and the LPIS custodian in charge needs to evaluate the parcel and establish the referenceArea, in other words, the maximum eligible area that can be claimed by the farmer(s) inside the parcel in question. This value should be communicated to the farmer(s) before the application campaign in spring. The attribute farmedArea is a sum of areas declared by the farmer(s) inside a reference parcel. It cannot exceed the referenceArea, and if it does, we have a case of over-declaration either by mistake or by fraud. The farmer’s applications connected to this reference parcel should be checked and the inconsistency should be resolved. The two remaining attributes, effectiveDate and status, are connected to the lifecycle of the reference parcel object in the database.

The *ReferenceParcel* class is an abstract class in the LCM model – it has five specialisations one per each reference parcel type. The attributes of the abstract class *ReferenceParcel* are mandatory to all its specialisations. The attribute that is the most important for all types of reference parcels is the *landCoverType* with *landCoverCodeType* code list to accommodate necessary values. In the context of the LCM, we speak about land cover only as the physical and biological cover of the earth's surface, which can be unambiguously mapped from orthophoto imagery or field survey. Therefore, arable land will be classified as arable land independently of any particular arable crop – wheat, rye, oats, etc. The use of area in terms of the type of crop or ground cover or the absence of a crop (Comm. Reg. 1122/2009 Art. 2) constitutes the use of agricultural land, and the term *land use* would be more appropriate instead. To avoid confusion, for land use concept we utilize *cropType* attribute with *cropCodeList*, which can be extended. Also, the *landCoverCodeList* is not exhaustive, and new codes can be added. For designing the attribute list for land cover the methodology proposed by FAO LCCS classification (Di Gregorio and Jansen, 2005) was applied. Classes can be extended applying the LCCS to reflect all physiognomic and structural aspects of land cover (Milenov, 2008) and to accommodate a variation of agricultural landscapes across Europe.

4.2.2. LCM packages

In addition to reference parcels' dataset, there are also several datasets necessary for checks for cross-compliance with environmental requirements and entitlements for rural development schemes as well as for geographic reference. One data source should be mentioned specially – it is orthophoto imagery. It is an aerial orthophoto at very detailed resolution from where the boundaries of reference parcels are originated and digitized. Also, the annual checks of a sample of farmers' applications are performed on the basis of the most recent, very high resolution (VHR) satellite or aerial imagery. In order to better handle different classes of the LCM, it was organized in packages (Figure 4.5). The other standardized schemas that are necessary to describe the geospatial content were added, namely *spatial schema*, *quality schema* and *the reference system schemas* of ISO/TC211 Harmonised Model. External classes of environmental domain were introduced from INSPIRE Consolidated Model.

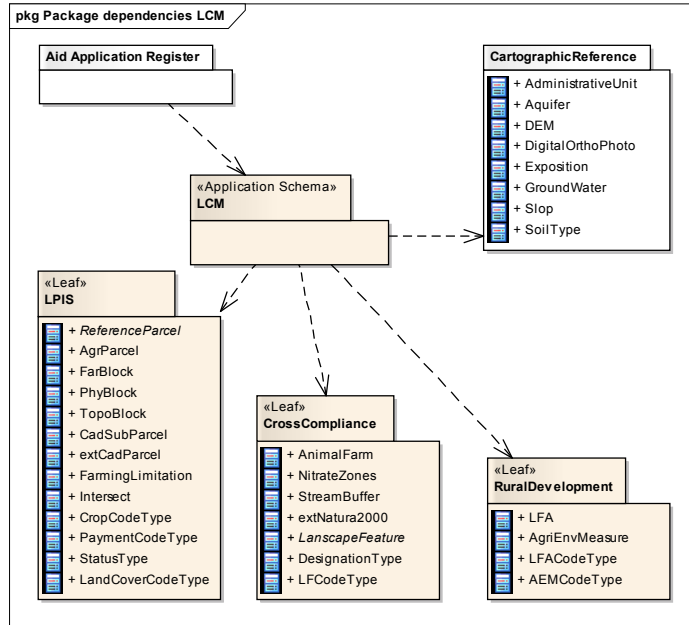


Figure 4.5. LCM packages and their content

4.3. Environmental issues in the LPIS

Each reference parcel can have none, one or several farming limitations from cross-compliance requirements and standards. They are handled through the class *FarmingLimitation* (Figure 4.6). Only farming limitations that have a spatial distribution and can be presented by spatial data layers are included in the LCM. The source datasets for farming limitations can be external data (e.g. *extNatura2000* class) or data especially created for the management of the CAP requirements (e.g. LFA – less favoured areas for agriculture). A reference parcel may be situated entirely inside or overlay with areas of cross-compliance. Therefore, we designed the *FarmingLimitation* and *Intersect* classes. The first one to hold information on type or relation and the latter to handle all possible options of overlay with three attributes – *resultArea*, *resultBoolean*, and *resultPercentage*.

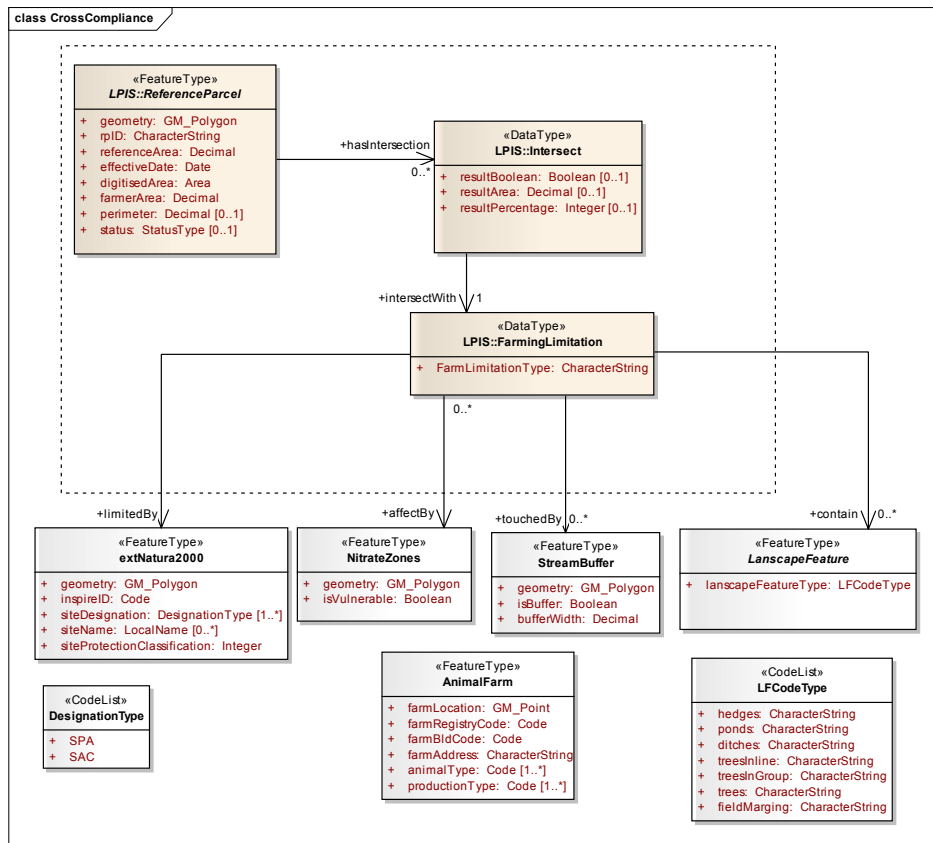


Figure 4.6. Modeling of farming limitations versus ReferenceParcel.

4.4. LCM and Land Administration

Paper 2 presents a collaboration data model between two domains: administration of the EU subsidies to the farmers and land administration (cadastral) domain. The use was made of two standardization initiatives: the LCM and the LADM (Land Administration Domain Model). One of the rationales for this work is the fact that several LPIS implementations in the member states are based on the national cadastre system (reference). In turn, for the LADM development, work described in Paper 2 illustrates the possibility for model extension into and integration with domains closely related to land administration, it supports the idea of integrated land administration system (LAS). The LCM version, which served as a basis for the collaboration model development is one presented in Paper 1. But it is important to mention that both models were evolving during preparation of Paper 2. Since there are some amendments in the LCM that were done later (Paper 3) and considerable changes were introduced into the LADM during working on ISO19152, some details in Paper 2 may not correspond to the most recent models' specifications.

Paper 2 examines core classes of both models and observes that both systems – LPIS and LAS – have in principle the same features: they are based on the relationships between people and land, linked by right to benefit from ownership or land use (tenure) with respect to restrictions and responsibilities. The core classes of LADM are presented in Figure 1 of Paper 2. The LADM core consists of LA_Party, LA_RRR (right, responsibility, restriction), LA_LAUnit (registered legal unit) and LA_SpatialUnit classes (see definitions in chap 2.1.3 of Paper 2). Class LA_RRR has three main specialisations LA_Right, LA_Responsibility, LA_Restriction.

A cadastral parcel is represented in the model by LA_Parcel, which is a specialization of the super class LA_SpatialUnit (see Figure 5, Paper 2). Following the Cadastre2014 principles (Kaufmann and Steudler, 1998, Kaufmann, 2004) of *spatial unit*, *legal independence* and of *linking objects by geometry* we have introduced a SubParcel (Figure 5 and Figure 6, Paper 2), which represents different agricultural land cover classes within the cadastral parcel and has a topological relationship with LA_Parcel. On the other hand, SubParcel is a specialization of the *ReferenceParcel* class of the LCM to insure its functionality in the CAP domain. In the spatial part of the collaboration model, the SubParcel is the only new class, which originally was not a part of the LADM nor of the LCM. The land cover classification for agricultural land is proposed considering the particular requirements of the CAP regulations and common practices used by the member states (see chap 2.2.2, Paper 2). However, in the newest version of the LCM the land cover classification has further evolved (Figure 4, Paper 3) due to changes in the CAP regulations and development of the quality assurance methodology.

The LCM as it presented in Paper 1 does not elaborate administrative, non-spatial classes of the IACS, except of AgriculturalParcel class. In Paper 2, more attention is put on further development of these classes in order to find correspondence between administrative classes in the LCM/LADM collaboration model. LA_Party and LA_RRR are two core classes coming from the LADM (Figure 7, Paper 2). The Farmer class of the LCM is designed as a specialization of LA_Party class in order to handle the attributes specific to farmers (Figure 9, Paper 2). From the LA_Party the Farmer class inherits its functionality to represent a physical person or association. The FarmingLimitation class is a specialization of LA_RRR:LA_Restriction. This association is not fully elaborate in the collaboration model because this part of the LCM is developed in-depth later, in Paper 3.

The PaymentEntitlement class (Figure 7, Paper 2) represents farmer's right to receive the EU subsidies, as it is recorded in entitlement register. It is interesting to notice, that we couldn't derive it from LA_RRR:LA_Right class of the LADM, since according to the CAP business rules entitlement is associated with farmer not with a land he/she cultivate – farmer can 'activate' his entitlement over different parcels.

4.5. LCM and EU Quality Assurance Framework for LPIS systems

The importance of the LPIS comes from the requirement that it must channel all area based aids; the corresponding financial value of direct payments exceeds 40bn € and roughly one-third of 12bn € of rural development funds in 2012. Both member states and the European Commission have therefore a keen interest in demonstrating the quality of the LPIS and in addressing quality issues, if any. Thus, the LPIS Quality Assurance Framework (QAF) was developed in 2009–2010 to address quality issues with first full implementation in 2010. QAF specifies quality requirements and series of tests to assess compliance for each specified quality requirement². The two main components of QAF are: (i) Model Conformance Test and (ii) Data Inspection Procedure Test. In Paper 3 these two components referred to as Abstract Test Suite (ATS) and Executable Test Suite (ETS). In order to facilitate QAF data exchange the LPIS Test Bed project was started at the end of 2009 (Paper 4). The LCM was used in the QAF in two ways: for a model conformance test and a schema transformation of an inspected dataset.

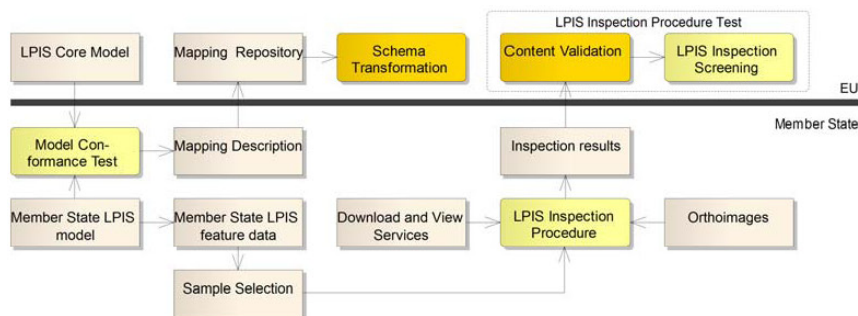


Figure 4.7. Simplified overview on Quality Assurance workflow.

The design of the ATS for was based on the methodology of the ISO19105 ‘Conformance and Testing’ (Paper 3). According to this methodology, the ATS is a set of generalized tests for particular requirements, which are independent of the actual implementation values, and positional, temporal or classification accuracy of the actual data. The ATS deals with the logical consistency and conceptual completeness of the data base structure, and checks whether the database design is ‘fit-for-purpose’. Conformity of the data model is a prerequisite for a meaningful data inspection. The actual testing of data quality for positional, temporal and thematic accuracy is specified by the ISO19105 as an Executable Test Suite (ETS) (Figure 4.8).

² <http://marswiki.jrc.ec.europa.eu/wikicap/index.php/Rationale>

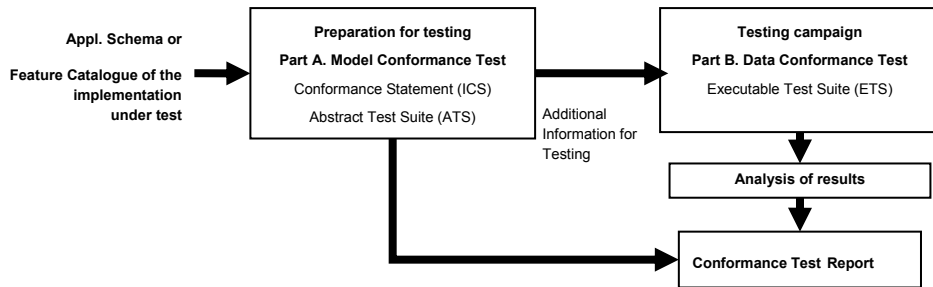


Figure 4.8. Conformance assessment process (after ISO 19105).

The modular structure and content of the proposed test suite are presented in the Figure 4 (Paper 3) and Annex IV of this thesis. Module A_11 consists of basic tests, which examine the concept of a reference parcel in use. The capability tests of module A_12 verified *how*, and most importantly, *where* in the database the area of eligible land is recorded. Model A_13 consists of three sub-modules. Sub-module A_131 tests show information about reference parcel is associated with polygon geometry – the attributes of ReferenceParcel class as they can be found in the implementation data model and their domain values. Sub-module A_133 deals with the specific attributes of reference parcel sub-type. In sub-module A_132, the representation of information relevant to the cross-compliance with environmental issues is tested. Each particular test of the modules A_12 and A_13 is assigned 'Conforming' if, for each element of the LCM, a corresponding feature from the LPIS under testing is found. The following information shall be documented for these features: (1) dataset / table; (2) layer; (3) attribute; (4) format; (5) domain values; (6, optional) definition including translation in English in order to prove semantic equivalence to the element in the LCM, if necessary. The records on findings for all tests shall be stored in the ATS-log report available as a template as well as an XML document schema. For the aggregation of the results on test suite level, a so-called 100% conformance has been proposed. ATS report consist of (i) *ATS-log* – list of findings per each particular test; (ii) *eligibility profile*³ clarifying national interpretation of land cover types according to FAO LCCS classification and (iii) *implementation conformance statement* describing implementation options.

Conclusions of the ATS trail (2009) and full implementation (2010) are presented in Paper 3. Three non-conforming reports (out of 42) identified a design issue, related to a failure or lack of a mandatory attribute of the reference parcel, in particular farmedArea, referenceArea and LandCoverType attributes; one non-conforming report identified the lack of the historical eligibility layer (additional feature for counties applying Single Area Payment Schema). Non

³ ftp://mars.jrc.ec.europa.eu/LPIS/Documents/v52_June2012/Annex_III_LC_concept_eligibility_ver5_2.pdf

conformity findings were taken on board and addressed in the formal remedial action plan.

Within the scope of LPIS Test Bed pilot study (Paper 4), model conformance is a prerequisite for successful schema transformation and a critical condition for the LPIS Inspection Procedure Test that is defined and described in LCM terms. The mapping between corresponding entities and their attributes is used as input for the related schema transformation web service. The mapping is also important in unambiguous understanding of the QA *quality elements* during Data Inspection Test by member state experts and data inspection results evaluation by Commission staff in semi-automated screening process. During study mapping descriptions for the transformation process (Figure 3, Paper 4) were created from ATS for three national test datasets and uploaded into the mapping repository. Two WFS services were established to publish national datasets of reference parcels, previously reduced by sample pre-selection procedure (ca. 800–1200 parcels). Data for schema transformation was provided through the transformation service.

5. DISCUSSION

During **modeling and quality testing** study CAP legislative requirements were formalised in the conceptual model with the goal of provision for a comprehensive conformity testing of the various LPIS systems. While working on the LCM and the test suite, author was also looking for a possibility to make the whole process of quality checking more automated, enabling quality monitoring of LPIS databases to be more simple, transparent and reliable. The case where a conceptual model used for assessing the uniform quality of distributed systems is new, since author has not found an equivalent example of usage of conceptual models in academic literature. Even in the INSPIRE process one can only find reports of the testing phase of conformance assessment between conceptual models and real databases with a goal ‘of finding gaps’ and ‘of demonstrating possibilities of new technologies’.

The LCM realization in the modular structure of UML packages supports a step-wise development and further extensions. The first step was to develop and refine the ReferenceParcel class (Paper 1, and further Paper 3) which is the central class of the LPIS package. It has turned out that a simple concept provided by a legal act – a spatial ‘container’ to identify farmer’s fields – can create a range of spatial objects, depending on agricultural practice, landscape particularity, and, sometimes, on the capacities of the land administration system in the country. It can be seen from questionnaire and the ATS reports that 12 implementations out of 43 have changed the type of reference parcel or re-thought its definition at least once in the 2006–2010 period. Some of those changes we can account to the findings of the LPIS audit by the Commission and, as a result, the better understanding of requirements; other changes can be explained by a desire to make the system more precise e.g. changing from physical block to farmer’s block. There are also systems, which apply more than one parcel type depending on the support scheme or different type of land use (e.g. commons in Ireland and UK); typically it is the combination of one reference parcel types with cadastral parcel (four cases).

The further analysis of requirements has lead to the development of the cross-compliance and rural development packages. Figure 4.6 presents only one of the possible modeling solutions; in practice, in LPIS systems there are two approaches of how cross-compliance data can be integrated with reference parcel data. The first approach is to calculate or re-calculate all data at the time of the reference parcel creation or update. Results are stored in a reference parcel layer via attributes or in special ‘consolidated’ tables. The second approach implies that values are produced ‘on-the-fly’ when they are needed for the administrative checks via dedicated database operations. The choice of approach depends on several considerations such as the need for speeding up the administrative checks or facilitating the work of operators and controllers. However, the existence of separate geographic layers, corresponding to data relevant to cross-compliances and holders for intersection results, is necessary for both approaches. In the model conformance test the authority, claiming

conformance with the legislation, needs to demonstrate the availability of data sources for cross-compliance checks in their systems.

If the LCM is a ‘correct translation’ of a legal text into the language of geoinformatics, than the ATS is the reverse reading of the LPIS implementation ‘back into legislation’. The fact that few non-conformance cases were found signifies that there were still ‘losses in translation’. The findings of the ATS are crucial for the start-up and progress with data inspection (ETS): the ATS ensures that the right datasets and layers are inspected and completeness and range of attribute checks can be performed by standard queries on features, layers and attributes identified in the ATS. In general, it has turned out from the ATS trail that the definition of the actual scope of the ATS (spatial features, layers and attributes to be included) is not a trivial task when a particular LPIS database accounts for tens datasets and layers. National application models are more complex than the LCM – they use aggregated identifiers, filters, etc. The low support for application schema and GML was also an issue as data custodians preferred to operate with old-fashioned data specifications in text format.

Land parcels differ by size and shape across Europe which is a logical reflection of biophysical conditions and land use practice, therefore LPIS data can be seen as reflection of European **agricultural systems**. LPIS/IACS data sets allow for clear distinction of two notions – land use and land cover – while more general classifications (e.g. CORINE) do not permit it. In the context of the IACS/LPIS, land cover is an instrument for identifying the potential eligibility of land. It can be unambiguously mapped from orthophoto imagery or a field survey, so land condition can be explicitly monitored and checked without respect to (intended) use via up-to-date reference parcels’ register. E.g. arable land will be classified as arable land independently of any particular arable crop – wheat, rye, oats, etc. or absence thereof (set-aside). Land use (=read ‘crop type’) is stored with agricultural parcel attributes, which are also contain information on what kind of support scheme(s) aid is claimed: single farm payment, specific crop’s support, organic farming, energy crops, agri-environmental afforestation etc.. Information on the agricultural parcel level, standing alone, does not contain any sensitive, person-related or financial information, which is part of the farmer’s application.

Therefore, the assessment of farming intensity, which is one of the central questions of agricultural systems’ research, becomes a more simple exercise. Diverse indices at different level can be derived from LPIS data starting with landscape metrics calculated from geometry. Then, for each explicitly mapped reference parcel we can derive the areas of arable land, pasture and particular crops from IACS databases. The share of different land classes can be a characteristic of farming intensity in its own right. But we can go further and assign the reference parcel statistical values of average yield and fertilisers consumption known for particular climate zones, farming systems and climate conditions of particular year and thus evaluate the input and output of an agricultural system avoiding the complicated procedure of allocation of farms’ economic statistics. Due to its very detailed mapping scale LPIS data is suitable

for assessment on regional, sub-regional and landscape level. In addition to its detailed scale, IACS data represents the whole population, in other words – all farms, and so can eliminate data distortions caused by farms sampling, when economic statistics are created. Due to explicit spatial allocation data can be easily aggregated to the higher levels, not necessarily of administrative division, but also related to ecological and landscape typologies. What is more, digitising landscape features as points, lines or polygons with their corresponding attributes in the LPIS, methodology which is already applied by several countries to build a landscape feature inventory, can be used in agricultural landscape related research. Harmonised model in this case will contribute to studies be comparable across EU countries.

When we are about to assess different agricultural systems the type of reference parcel should also be taken into consideration, namely how closely a reference parcel matches a production unit – field –, especially when methodology developed in one country or one region is applied in another part of Europe. System applying single field parcel are the most detailed, where each field has explicit geographic location, but they are costly. The physical block is the loosest mapping, but its advantage is that the database can be created and maintained by responsible institution only on the basis of land cover information from imagery. Therefore, to apply the physical block system was the easiest way to create initial LPIS from scratch. Farmer's block type is a tighter allocation of farming activity, but involves interaction between the administration and the farmer to explicitly define the block. This solution is suitable for countries with stable land use patterns based on ownership or tenure (e.g. in France the agricultural land tenure is regulated by the minimum rent contract duration, which is nine years). Cadastral parcel represents ownership and may differ from actual land use. Consequently, single crop parcel and farmer's block allow for tighter coupling of land cover and economic characteristics, then cadastral parcel and physical block.

The minimum set of land cover types (LandCover::LandCoverCodeType, Figure 4.4) was being expanded by eligibility profile (not a part of this thesis), which became part of the ATS in 2010. Eligibility profile is an attempt to provide semantic descriptions to the variety of national-specific understandings of what general land cover class envelopes, e.g. different types of pasture or natural grassland, by means of FAO Land Cover Classification System (LCCS) classifiers. Particularly important for data inspection, this interesting approach can be further extended for studies of different agricultural systems in Europe.

In the case of LPIS quality assurance framework and LPIS Test bed we can speak of *in-domain interoperability*: an attempt of data harmonisation for uniform reading, demonstrating and monitoring of system consistency. It was not a classical case when the target is to create a uniform homogeneous data set or transform data between systems. The interoperability in this case results in harmonisation across domain and in making data available between different actors of business process – LPIS custodians and the auditing authority. Schema mapping and transformation services technology allow the auditing authority

access data of different or even all member states in a similar way. Once the schema mapping is established and uploaded into mapping repository this setup can serve for several quality checks, repeated on a periodical basis for several pre-selected sets. However, the business rules of such an approach still need to be agreed on by all stakeholders. On the other hand *cross-domain* interoperability presents the integration of various environmental data with LPIS. As in the case of in-domain issue, there is no mismatch in semantic; particular use case – insuring environmentally friendly agricultural practice – needs exchange and reuse of native concepts of environmental management requirements. Harmonised models of *e.g.* INSPIRE theme for protected areas can be read from agricultural domain and *vice versa*: INSPIRE specification for land cover (INSPIRE D2.8 annex B) can refer to and describe data sources from agricultural domain via the LCM. Here we don't speak about integration of different land cover data into IACS/LPIS, since the main task of the system is monitoring eligibility via frequent update of its own land cover data set. However in case of possible re-use and harmonisation with other data sources of such multifunctional themes as land cover, the semantic transformation will be definitely needed by means of *e.g.* a Land Cover Meta Language (LCML) proposed by ISO19144-2 and based on LCCS of FAO or Pure Land Cover Component (PLCC, INSPIRE D2.8) classification of the EAGLE group⁴.

In case of collaboration of two domains – land administration and management of subsidies – we have two, seemingly similar, operational systems with different backgrounds and goals. In this case the *semantic* interoperability is a main concern. The mapping of concepts is feasible, but to be operational from both collaborative domains we need an intermediate element (Paper 2: Sub-parcel class) which responds to requirements of both systems. The implementation of such a model might be non-trivial firstly because LAS data that represents legal ownership aspects of land does not always fit well with real world land use/ agricultural practice. In countries where this gap is big (and no improvement is expected in the near future) one can conclude that cadastral parcel layer in LAS are of little use as basis for reference parcels in IACS/LPIS. Reference parcel boundaries and, more importantly eligibility of land, are out of scope of conventional LAS and frequent update procedure required by CAP legislation is an additional task which needs extra capacity. So, the proposed model may only be implemented in the countries ready or willing (by taking the necessary measures to improve their LAS if needed) to use their LAS for IACS purpose.

In development of the LCM (and LPIS) a challenge of the near **future research** would be new functionality needed for implementation of the recent proposal for the CAP after 2013, including 'greening' of direct payments, the sustainable management of natural resources and climate actions. Current functions of the LPIS to support control needs to be extended towards greening measures: crop repartition, ecological focus areas and preservation of permanent

⁴ <http://sia.eionet.europa.eu/EAGLE/#Links>

grassland. It is very likely that functionality of the LPIS would be extended also into monitoring and evaluation of policy impact, therefore meaningful, simple and repeatable set of indicators would be needed. The quality assurance framework should be revised to accommodate new cases of conformity and the experience of data inspections (especially in mapping of different land cover types) should be analysed and summarised. For further development of the prototyped web services Paper 4 identifies several aspects which have to be taken into consideration such as (i) increasing robustness and usability of the services; (ii) their integration into prospective LPIS geoportal implementation; (iii) for interoperability and standardisation an eye should be kept on the corresponding technological development.

CONCLUSIONS

The following conclusions can be drawn from this thesis:

1. Conceptual modeling is a comprehensive and flexible tool, suitable for embracing a wide range of concepts, their specialisations and interrelations. The LCM realization in the modular structure of UML packages supports a step-wise development on further extensions, in pace with the needs and priorities. Standardisation and harmonisation process should not add or remove any features from a well-designed operational LPIS. Harmonised model however is needed to provide for a formal and uniform reading of that system. Building upon the methodological framework of ISO 19100 and INSPIRE principles allowed to concentrate on specific universe of discourse and its business rules while spatial objects, temporal primitives, metadata etc. can be reused from foundation models. Other spatial objects on the borderline with other domains such as environmental or land administration can be incorporated via integration or collaboration approaches. The standardised schemas of ISO/TC211 Harmonised Model allowed for reuse of models of geometric primitives and quality elements (*spatial schema, quality schema*).
2. For quality issues of distributed heterogeneous system – as LPIS across the EU are – assessment of the logical consistency by means of a model conformance test allows to judge if the system is ‘fit-for-purpose’. This test is a transparent and reputable procedure, which is able to demonstrate system quality and even improvement in logical consistency in the case of major upgrade or redesign of the system.
3. The LCM allows the uniform reading of the system under test through a transformation service and permits an efficient screening of data inspection results. The developed Test Bed services demonstrate the feasibility of the chosen SDI-approach for LPIS Quality Assurance. A Web service for the transformation of heterogeneous LPIS database implementations towards the common model as well as a Web service for the validation of data inspections were designed, implemented and successfully tested in laboratory conditions.
4. The exercise of developing a collaboration model for LCM/LADM shows that implementation of such collaboration between two domains related to ‘*land-people relationship*’ is possible, but it is not a trivial task. Business rules of two well established systems as well as requirements to and live cycle of what is called in both systems *land parcel* are different despite apparent similarity. Proposed solution – *SubParcel*, topologically related to cadastral parcel – implies the maintenance of an additional layer, which is out of scope of conventional LAS and would require an additional capacity from the cadastral system.

5. Environmental issues in the LPIS rely on datasets, which are not always maintained inside the system; many of them are of cross-domain nature. The LCM can integrate parts of the other standardised schemas based on thematic requirements of other domains. At current stage external extNatura2000 class is introduced from INSPIRE Consolidated Model, but with further development of the INSPIRE Annex II and III specifications such themes as land cover and orthophoto can be added. The mechanism provided by *FarmingLimitation* and *Intersect* classes allows establishing a spatial relation between reference parcel and environmental classes.
6. LPIS/IACS data can be used for improving the results of well established indicators and in the development of new indicators and monitoring procedures. The advantages are (i) detailed spatial resolution making use of landscape metrics technique possible; (ii) the fact that data presenting full population (data is not aggregated) eliminates calculation distortions; (iii) separate representation of land cover and land use concepts.

Annexes

Annex I: List of concepts, which are relevant to content of the LCM

| | |
|--|--|
| Farmer Art. 2 Council Reg. 73/2009 | means a natural or legal person, or a group of natural or legal persons, whatever legal status is granted to the group and its members by national law, whose holding is situated within Community territory, as defined in Article 299 of the Treaty, and who exercises an agricultural activity; |
| Agricultural activity Art. 2 Council Reg. 73/2009 | means the production, rearing or growing of agricultural products including harvesting, milking, breeding animals and keeping animals for farming purposes, or maintaining the land in good agricultural and environmental condition as established in Article 6; |
| Single Farmer's Application Art. 19 Council Reg. 73/2009 | Each year, a farmer shall submit an application for direct payments indicating, where applicable: (a) all the agricultural parcels on the holding, and where the Member State is applying Article 15(3), the number of olive trees and their positioning in the parcel; (b) the payment entitlements declared for activation; (c) any other information provided for by this Regulation or by the Member State concerned. |
| Payment schemes Art. 1, Annex I Council Reg. 73/2009 | (b) 'single payment scheme' (SPS) – an income support scheme for farmers (c) 'single area payment scheme' (SAPS) – a transitional simplified income support scheme for farmers in the new Member States as defined in Article 2(g) (d) support schemes for farmers producing rice, starch potatoes, protein crops, nuts, seeds, cotton, sugar, fruit and vegetables, sheep meat and goat meat and beef and veal; (Title V schemes) |
| Entitlements Art. 33 Council Reg. 73/2009 | Support under the single payment scheme, which shall be available to farmers if they: (a) hold payment entitlements which they have obtained in accordance with Regulation (EC) No 1782/2003; (b) obtain payment entitlements under (this) Regulation (EC) No 73/2009: (i) by transfer; (ii) from the national reserve; (iii) pursuant to Annex IX; (iv) pursuant to Art 47(2), Art 59, Art 64(2), Art 65 and Art 68(4)(c). |
| Eligible hectare Art. 34 Council Reg. 73/2009 | Support under the single payment scheme shall be granted to farmers upon activation of a payment entitlement per eligible hectare. Activated payment entitlements shall give a right to the payment of the amounts fixed therein. shall mean: (a) any <i>agricultural area</i> of the holding, and any area planted with short rotation coppice that is used for an <i>agricultural activity</i> or, where the area is used as well for non-agricultural activities, predominantly used for <i>agricultural activities</i> ; and (b) any area which gave a right to payments under the single payment scheme or the single area payment scheme in 2008 and which: |

| | |
|--|--|
| <p>Art. 55(3) Council Reg. 73/2009</p> | <p>(i) no longer complies with the definition of ‘eligible’ as a result of the implementation of Directive 79/409/EEC on the conservation of wild birds, Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora and Directive 2000/60/EC establishing a framework for Community action in the field of water policy; or (ii) for the duration of the relevant commitment of the individual farmer, is afforested pursuant Council Regulation (EC) No 1257/1999 on support for rural development; or (iii) for the duration of the relevant commitment of the individual farmer, is set aside pursuant Regulation (EC) No 1257/1999 or to Regulation (EC) No 1698/2005.</p> <p>Except for Bulgaria and Romania, any new Member State having applied the single area payment scheme may provide that, in addition to the eligibility conditions established in Article 34(2), ‘eligible hectare’ shall mean any agricultural area of the holding which has been maintained in good agricultural condition on 30 June 2003, whether or not in production at that date.</p> |
| <p>Cross-compliance Art. 4, 5 and 6 Council Reg. 73/2009</p> | <p>A farmer receiving direct payments shall respect the statutory management requirements (SMR) listed in Annex II and the good agricultural and environmental condition (GAEC) referred to in Article 6. The obligations referred to in the first subparagraph shall apply only in so far as the agricultural activity of the farmer or the agricultural area of the holding is concerned.</p> <p>The SMR listed in Annex II shall be established by Community legislation in the following areas:</p> <p>(a) public, animal and plant health; (b) environment; (c) animal welfare</p> <p>Member States shall ensure that all agricultural land, especially land which is no longer used for production purposes, is maintained in good agricultural and environmental condition. Member States shall define, at national or regional level, minimum requirements for good agricultural and environmental condition</p> |
| <p>Holding Art. 2 Council Reg. 73/2009</p> | <p>– means all the production units managed by a farmer situated within the territory of the same Member State;</p> |
| <p>Agricultural area Art. 2 Council Reg. 73/2009 Art 2 Comm, Reg 1120/2009</p> | <p>– means any area taken up by arable land, permanent pasture or permanent crops (relevant definitions Comm. Reg. 1120/2009 art. 2):</p> <p>(a) ‘arable land’ means land cultivated for crop production or maintained in good agricultural and environmental condition in accordance with Article 6 of Regulation (EC) No 73/2009, irrespective of whether or not that land is under greenhouses or under fixed or mobile cover;</p> <p>(b) ‘permanent crops’ means non-rotational crops other than permanent pasture that occupy the land for five years or longer and yield repeated harvests, including nurseries, and short rotation coppice;</p> <p>(c) ‘permanent pasture’ means land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the</p> |

| | |
|---|--|
| | <p>holding for five years or longer, excluding areas set aside in accordance with Council Regulation (EEC) No 2078/92, areas set aside in accordance with Articles 22, 23 and 24 of Council Regulation (EC) No 1257/1999, and areas set aside in accordance with Article 39 of Council Regulation (EC) No 1698/2005; and to this end, ‘grasses or other herbaceous forage’ means all herbaceous plants traditionally found in natural pastures or normally included in mixtures of seeds for pastures or meadows in the Member State (whether or not used for grazing animals). Member States may include arable crops listed in Annex I;</p> <p>(d) ‘grassland’ means arable land used for grass production (sown or natural); for the purposes of Article 49 of Regulation (EC) No 73/2009 grassland shall include permanent pasture;</p> |
| <p>Agricultural parcel Art 2 Comm. Reg.1122/2009</p> | <p>a continuous area of land, declared by one farmer, which does not cover more than one single crop group;</p> <p>however, where a separate declaration of the use of an area within a crop group is required in the context of this Regulation, that specific use shall if necessary further limit the agricultural parcel;</p> <p>Member States may lay down additional criteria for further delimitation of an agricultural parcel (also known as production unit);</p> |
| <p>Crop group Art 56 Comm. Reg.1122/2009</p> | <p>– ... the following crop groups shall be distinguished as appropriate:</p> <p>(a) areas declared for the purposes of activation of payment entitlements under the single payment scheme, as the case may be, each fulfilling the conditions particular to them;</p> <p>(b) areas for the purposes of the single area payment scheme in accordance with Chapter 2 of Title V of Regulation (EC)No 73/2009;</p> <p>(c) a group for each of the areas for the purpose of any other area-related aid scheme, for which a different rate of aid is applicable;</p> <p>(d) areas declared under the heading ‘other uses’.</p> |
| <p>Reference parcel Art 2 Comm. Reg.1122/2009</p> <p>Art 6(1) Comm. Reg.1122/2009</p> | <p>means a geographically delimited area retaining a unique identification as registered in the GIS in the Member State’s identification system referred to in Art. 15 CR. 73/2009. (also known as production block)</p> <p>The identification system for agricultural parcels referred to in Article 17 of Regulation (EC) No 73/2009 shall operate at reference parcel level such as cadastral parcel or production block which shall ensure unique identification of each reference parcel.</p> <p>For each reference parcel, a maximum eligible area shall be determined for the purpose of the single payment scheme or the single area payment scheme. The GIS shall operate on the basis of a national coordinate reference system. Where different coordinate systems are used, they shall be compatible within each Member State.</p> |
| <p>(agricultural) use Art 2(15) Comm. Reg.1122/2009</p> | <p>means the use of area in terms of the type of crop or ground cover or the absence of a crop;</p> |
| <p>Area determined Art 2(23) Comm. Reg.1122/2009</p> | <p>means the area for which all conditions laid down in the rules for granting the aid have been met; in the case of the single payment scheme, the area declared may be deemed as being determined only if it is actually being accompanied by a corresponding number of payment entitlements;</p> |

Annex II: List of SMR with geographic component

| SMR | Description | GI component |
|--------|---|--|
| | Environment | |
| SMR1 | conservation of wild birds | – Special Protection Areas (SPAs) of NATURA 2000 – identified habitats (nests and buffers) |
| SMR2 | protection of groundwater against pollution | – groundwater depth – depth of aquifer – soil types (infiltration, porosity) (classified by vulnerability) |
| SMR 3 | protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture | – soil types (infiltration, porosity) classified by vulnerability |
| SMR 4 | protection of waters against pollution caused by nitrates from agricultural | – nitrate vulnerable zones (with account on slops and erosion and soil types) |
| SMR 5 | conservation of natural habitats and of wild flora and fauna (Habitat Directive) | – Special Areas of Conservation (SACs) NATURA 2000 |
| | Public and animal health | |
| | Animals identification | |
| SMR 6 | Identification and registration of animals (pigs only) | – sty, farm location |
| SMR 7 | ear tags, passports and holdings registers – (cattle) | – cattle farm, barn location |
| SMR 8 | identification and registration of bovine animals and regarding the labelling of beef and beef products | – farm, barn location |
| SMR 8a | identification and registration of ovine and caprine animals and | – shed location |
| | Public plant and animal health | |
| SMR 9 | placing of plant protection products on the market | NA |
| SMR 10 | on the use in stock farming of certain substances having a hormonal or thyrostatic action and of betaagonists | NA |
| SMR 11 | matters of food safety | NA |
| SMR 12 | rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies. | |
| | Notification of diseases | |
| SMR 13 | Foot and Mouth Disease. | – farms' location |
| SMR 14 | animal diseases and specific measures relating to swine vesicular disease. | – farms' location |
| SMR 15 | Bluetongue disease | – farms' location |
| | Animal welfare | |
| SMR 16 | calves | NA |
| SMR 17 | pigs | NA |
| SMR 18 | Protection of animals kept for farming purpose | NA |

Annex III: List of GAEC standards with geographic component
(optional standards are in *Italic*)

| Issue | Standards <i>(optional standards are in Italic)</i> | GI component |
|--|---|---|
| 1. Soil erosion: | <ul style="list-style-type: none"> – Minimum soil cover – Minimum land management reflecting site-specific conditions – <i>Retain terraces</i> | Soil layer, slopes Landscape feature: terraces |
| 2. Soil organic patten: | <ul style="list-style-type: none"> – Arable stubble management – <i>Standards for crop rotations</i> | |
| 3. Soil structure: | <ul style="list-style-type: none"> – <i>Appropriate machinery use</i> | |
| 4. Minimum level of maintenance: | <ul style="list-style-type: none"> – Retention of landscape features, including, where appropriate, hedges, ponds, ditches, trees in line, in group or isolated and field margins (appl. 2010) – <i>Minimum livestock stocking rates or/and appropriate regimes</i> – <i>Establishment and/or retention of habitats(appl. 2010)</i> – Avoiding the encroachment of unwanted vegetation on agricultural land – <i>Prohibition of the grubbing up of olive trees</i> – Protection of permanent pasture – <i>Maintenance of olive groves and vines in good vegetative condition</i> | Landscape features' layer Orthophoto Permanent pasture registry |
| 5. Protection and management of water: | <ul style="list-style-type: none"> – Establishment of buffer strips along water courses (app. 2012) – Where use of water for irrigation is subject to authorisation, compliance with authorization procedures (appl. 2010) | Network of water courses where measures applied, buffer strips |

Annex IV: Full structure of the Abstract Test Suite

| Module | Test | Conformance topic |
|-------------|-----------|---|
| Module A_11 | | Definition of reference parcel |
| | A_111 | definition of reference parcel: boundaries |
| | A_112 | definition of reference parcel: land cover |
| | A_113 | Physical block |
| | A_114 | Farmer's block |
| | A_115 | Agricultural parcel |
| | A_116 | Topoblock |
| | A_121–123 | Cadastral parcel |
| Module A_12 | | Eligible Land Type of reference parcel (land cover) |
| | A_121 | Eligible land types |
| | A_122 | Historical eligibility (referred to yr 2003) |
| (optional) | A_123 | Ineligible land types |
| (optional) | A_124 | Landscape Features |
| Module A_13 | | Reference parcel attributes |
| Sub-module | A_131 | Obligatory attributes |
| | A_1311 | Reference parcel identifier |
| | A_1312 | Reference area |
| | A_1313 | Effective date |
| | A_1314 | GIS area |
| | A_1315 | Area claimed inside parcel |
| | A_1316 | Validity status |
| Sub-module | A_132 | Attributes for cross-compliance |
| | A_1321 | Less Favoured Areas |
| | A_1322 | Bird protection site (inside of the parcel, Y/N) |
| | A_1323 | Nitrate directive (coverage) |
| | A_1324 | NATURA & Habitat |
| | A_1325 | Soil protection measures |
| Sub-module | A_133 | Specific attributes of Reference Parcel types |
| | A_1331 | farmID or farmerID; |
| | A_1332 | crop group (land use) |
| | A_1333 | crop (land use) |
| | A_1334 | land cover |
| | A_1335 | payment type |
| | A_1336 | perimeter |

SUMMARY IN ESTONIAN

Põllumassiivide identifitseerimissüsteemi kontseptuaalne mudel: geoinfo huvigrupi kontseptuaalse mudeli loomine

Käesolevas doktoritöös käsitletakse Põllumassiivide identifitseerimissüsteemi (*Land Parcel Identification System, LPIS*) Kontseptuaalse Mudeli (*LPIS Conceptual Model, LCM*) loomist ja selle kasutamist ruumiandmete standardiseerimisel, kvaliteedi hindamisel ja koostoimimisel teiste valdkondade ruumiandmetega. Mudelis käsitletud ruumiandmeid kasutatakse põllumajandustoetuste haldamise ja kontrolli eesmärgil ELi Ühise PõllumajandusPoliitika (ÜPP) raames.

ÜPP raames makstavate toetuste haldamiseks on igas EL liikmesriigis asutatud Ühtne haldus-ja kontrollisüsteem (*Integrated Administrative ja Control System, IACS*), mille ruumiandmeid haldav komponent on põllumassiivide identifitseerimissüsteem. Nõue kaardistada ja registreerida toetuskõlblik maa on viinud olukorrani, kus põllumajandussektoris on tekkinud suur hulk ruumiandmeid. Viimase aastakümne jooksul on kasvanud ÜPP-ga seotud geoinformaatika sektor Euroopas. ÜPP-ga seotud geoinfo huvigrupp (*Spatial Data Interest Community*) hõlmab nii andmete tootjaid, haldajaid ja kasutajaid, kui ka IT rakenduste arendajaid ning kaugseire andmete tarnijaid. Vajadus hinnata LPIS kvaliteeti ja selle vastavust EL määrustele ning tagada koostalitlusvõime keskkonnaalaseid nõudeid toetavate ruumiandmete ja süsteemidega, kutsus esile LCM-i loomise. Töö eesmärgiks oli edendada kontseptuaalmodelleerimist ruumiandmete kvaliteedi hindamisel LPIS valdkonnas ja teiste geoinfo valdkondadega koostalitlusvõime arendamisel.

LCM väljatöötamise metodoloogia aluseks oli ISO19100 seeria rahvusvaheliste standardite meetodika, mida samuti rakendavad ja laiendavad INSPIRE direktiivi printsiibid ja millele keskendutakse uurimistöo teoreetilises osas. Mudeli peamiseks sisendiks said ÜPP-d reguleeritavates määrustes sätestatud kontseptsioonide põhjalik käsitus ja olemasolevate töötavate süsteemide analüüs, mis põhineb LPIS küsitluste tulemustel (Milenov ja Kay, 2006; Zieliński ja Sagris, 2008 ja 2009) ja hõlmab erinevate liikmesriikide LPIS süsteeme.

Väitekirja sisulised põhitulemused on esitatud tööle lisatud publikatsioonides. Publikatsioonis 1 on keskendutud ÜPP otsetoetuste ärimudeli analüüsile ehk ÜPP toetustesüsteemi põhikontseptsioonidele, tehtud kokkuvõtted ja järeldused 2006. ja 2008. aasta LPIS küsimustikust. Aastal 2007 valmis LCM algne versioon, mis avati *online* aruteluks IACS ruumiandmete kasutajate huvigrupile (*Spatial Data Interest Community*) (Devos *et al.*, 2007). Selle tulemusena valmis LCM esimene versioon, mis on esitatud Publikatsioonis 1 (2008). LCM keskmes on kaks klassi: ReferenceParcel ehk põllumassiiv ja AgriculturalParcel ehk toetustaotluses deklareeritud põld. ReferenceParcel-i klassi ülesandeks on toetuskõlbliku põllumaa identifitseerimine, lokaliseerimine ja pindala määramine. ReferenceParcel täidab 'konteineri' rolli deklareeritavate maatükkide suhtes. Publikatsioonis 1 on ka käsitletud põllumassiiviklassi alamtüüpe ning

analüüsitud erinevaid põllumajanduslikke maakatte klassifitseerimise ja kaardistamise lähenemisviise.

Publikatsioonis 2 on otsitud võimalusi kahe mudeli – LCM ja Maakatastri valdkonna mudeli (*Land Administration Domain Model, LADM*) – lõimiseks. Selleks on kasutatud LCM arendamisega paralleelselt toimuva ISO19152 – LADM väljatöötamise algatust. Kaks mudelit on omavahel integreeritud uue ruumilise klassi SubCadParsel abil – katastriüksuse sees eristuvad maakatte tüübi alamüksused. Publikatsioonis 2 käsitletakse ka mõlema mudeli semantiliselt sarnaseid haldusklassse ja tehakse kindlaks uued seosed kahe mudeliklassi vahel. Ära on toodud põhjalik analüüs, millistes reaalse elu tingimustes võiks toimida kahe mudeli integreerimine.

Publikatsioonis 3 on esitatud LCM viimane versioon. See keskendub kahele aspektile: (i) nende klasside modelleerimisele, mis toetavad vastavust keskkonna, tervise ja loomade heaolu majandamisnõuetele ning mis toetavad maa heade põllumajandus- ja keskkonnatingimuste kontrolli; (ii) mudeli kasutamisele LPIS süsteemide ja andmebaaside loogilise õigsuse (ehk EL määruste nõuetele vastavuse) testimiseks. Selleks on välja töötatud ISO19105 standardil põhinev testide kogum (*Abstract Tests Suite, ATS*), mis võimaldab kaardistada olemasolevaid LPIS registreid vastavalt LCM skeemile. ATS töötati välja ja testiti koostöös mitmete EL liikmesriikidega ja selle metodoloogia on osa Euroopa komisjoni poolt kehtestatud LPIS kvaliteedi tagamise raamprogrammist alates 2010. aastast.

Publikatsioon 4 käsitleb LCM kasutamist LPIS testimise portaali prototüübi loomisel, mis koondas enda alla OGC ühilduvaid veebiteenuseid. Nende eesmärgiks on võimaldada andmevahetust põllumassiivide rahvuslike süsteemide ja auditeerijatega Euroopa komisjonist. Eelvalitud põllumassiivide geograafiliste kihtide temaatilist ja positsioonilist õigsust kontrolliti liikmesriikide ekspertide poolt kõrge resolutsiooniga kaugeisre andmete taustal. Selleks et võimaldata auditeerijate juurdepääsu kvaliteedikontrolli tulemustele, loodi kolm prototüüp-veebiteenust, kus kasutati LCM originaalandmete transformeerimiseks.

Edasised uuringud (publikatsioon 5) kontsentreeruvad erinevate Euroopa põllumajandussüsteemide kajastamisele LPIS andmetes ja nende andmete kasutamise võimalustele põllumajanduspoliitika keskkonnamõju hindamisel. LPIS/IACS põhikontseptsioonid vaadatakse uuesti läbi, nüüd juba mõjuhindamise ja indikaatorite väljatöötamise kontekstis. Teoreetilist arutlust illustreerib kõrge loodusväärtusega põllumajandusmaa (HNV) indikaatorite väljatöötamise näide Jõgevamaal – põlluregistrist saadud detailiderohked andmed lubavad arvutada nii maastiku meetrika kui ka põllumajandusintensiivsuse indikaatoreid, seejuures tüpiseerides põllumajandussüsteemide erinevaid aspekte.

Seega, LCM toetab geograafiliste andmete harmoniseerimist ja koostalitlusvõimet mitmel moel: (i) pakkudes valdkonna siseselt andmete ühiselt mõistetavat tehnilist lugemist, nii mudeli vastavusetesti (ATS) kui ka veebiteenuste kaudu transformeerimisel; (ii) võimaldades semantilise vastavuse leidmist ja andmete/süsteemide integreerimist erinevate geoinfo valdkondade vahel.

Loodud ja arendatud esialgselt Euroopa komisjoni LPIS kvaliteedisüsteemi vajadusi silmas pidades, võimaldab LCM erinevate liikmesriikide põllumajandusregistrите andmete ühiselt mõistetavat lugemist ka teistes valdkondades. LCM on lisatud kasutusjuhtumina rahvusvahelise standardi ISO 19152 *'Land Administration Domain Model'* lisasse H ja INSPIRE DS2.8 *Land Cover* rakenduseeskirja lisasse B2.

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