

LAND COVER AND LAND USE RESEARCH FOR A CREATION OF A NATIONAL MAPPING AGENCY FRAMEWORK

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ABSTRACT:

Historically Ordnance Survey has collected information on land cover and land use but as this for primarily cartographic purposes it has not been done in a methodical and comprehensive way. As a result the land cover and land use information currently captured by Ordnance Survey fits more into historic cartographic categories than a classification system designed to be used for computational purposes.

In future, the challenge for a National Mapping Agency is that designing a classification system that can respond to the needs of a variety of users, and where all possible end uses cannot be known *a priori*. However, there is no one ideal or universal classification of land use and land cover. A review of different land cover and land use classifications within the UK shows that a classification is usually designed for a particular purpose, a particular geographical area or a particular user. An attempt to create a national categorisation of land use and land cover was the NLUD (National Land Use Database) classification. However, this has gained little traction within government agencies and it lacks the degree of flexibility that a national classification should allow for.

Our research has concentrated on two different levels: (i) the design of a flexible framework that would allow for the integration and relation of different classification systems and taxonomies and (ii) the design of an ontology and a high level classification system for use with data collected from different sources including remote sensing and GIS and fit for the purposes of a National Mapping framework.

A test performed in the urban area of Bournemouth has showed promising results. This test has helped to identify what research needs to be done next in terms of methods and data.

1. INTRODUCTION

Land Cover and Land Use Information are widely used by different governmental and commercial organisations in a variety of ways and it is collected and classified differently for every single purpose. However it is currently not possible to link all these data in order to have an integrated set of information at national, regional or even local level.

As a National Mapping Agency we could potentially provide a land cover and land use framework that could respond to the needs of a high variety of users. Although Ordnance Survey currently collects land cover and land use information this is not done in a comprehensive way and it is not delivered to our users in a clear manner. If we were to provide a framework we would have to design a structured data capture, a system for the integration of current classifications and a high degree of flexibility so that users can customise this information for their own purposes. In this paper we will (i) describe the partitioned land cover and land use information scene in the United Kingdom, and (ii) describe the structure for an ontological framework that could help to ultimately incorporate all this information and (iii) describe a trial in an urban area south of the United Kingdom (Bournemouth) that was performed in order to identify further research.

1.1 Current Land Cover and Land Use classifications in the UK

It is well known that land cover and land use information has become increasingly important in order to make many types of national, regional and local decisions. Problems such as natural hazards, uncontrolled development and deteriorating environmental quality need quality and up to date information on land cover and land use.

However, there has been an uncoordinated attempt to categorise and classify different land cover and land use classes by different organisations. All these classifications are some how subjective and there is not a single way of describing the reality that surround us (Lofvenhaft et al. (2002)). A look at different land cover and land use classifications within the UK shows that a classification is usually designed for a particular purpose, a particular geographical area or a particular user. According to the Joint Nature Conservation Committee (JNCC) the more widespread classifications used within the UK are:

1.1.1 Biodiversity Action Plan Priority Habitats: These priority habitats cover a wide range of semi-natural habitat types that are judged to be particularly important for biodiversity conservation. The list of priority habitats comprises 65 habitats.

1.1.2 Biodiversity Action Plan Broad Habitats: This classification was developed as part of the UK Biodiversity Action Plan. The Broad Habitats are the framework through which the Government is committed to meet its obligations for monitoring in the wider countryside. The list of Broad Habitats consists of a list of 27 Broad Habitats.

1.1.3 Marine Habitat Classification: The Marine Habitat classification for Britain and Ireland provides a tool to aid the management and conservation of marine habitats. The classification is presented in hierarchical format, and through a series of habitat matrices. It comprises 5 Broad Habitat types, 24 Habitat complexes, 75 Biotope complexes, and 370 Biotopes and Sub-Biotopes.

1.1.4 National Vegetation Classification (NVC): The NVC aims to describe the whole range of British vegetation as a series of plant communities. The NVC comprises 286 community types subdivided amongst 12 major types of vegetation. Many, but not all, of the NVC communities are broken down further into sub-communities, which total 578 in all. A very small number of especially bulky and complex communities have a third level of sub-division, into variants.

1.1.5 Phase 1 Habitat Classification: The Phase 1 Habitat Classification and associated field survey technique provide a standardised system to record semi-natural vegetation and other wildlife habitats. The Phase 1 classification comprises ten broad high level categories. Amongst these, 155 specific habitat types are recognised, each having its own name, alpha-numeric code, description and mapping colour.

1.1.6 Vegetation communities of British lakes: The first comprehensive classification scheme for standing waters in Britain (Palmer 1992; Palmer et al. 1992) was based on macrophyte surveys carried out by the Nature Conservancy Council (NCC) from 1124 standing waters throughout England, Scotland and Wales between 1975 and 1988. This dataset became an important source of information used for a variety of purposes including conservation site selection and the identification of aquatic communities in the National Vegetation Classification (NVC). It shows separate ecological descriptions of 11 distinct lake groups.

1.1.7 BTO Bird Habitat Coding Scheme: The list of species officially recorded in Great Britain is maintained by the British Ornithologists' Union. Information on habitats occupied is derived from the BTO's Breeding Bird Survey. There are four different levels within the classification. There are 10 habitats in the first level and 60 in the second level, 70 in the third level and 88 in the fourth level.

1.1.8 Peterken Woodland Stand Types: The Stand Type system (Peterken 1981) divides woodland into twelve Stand Groups and 39 Stand Types largely on the basis of the trees and shrubs, but also using some soil characters. It was the main woodland classification system used by the conservation 7 agencies from 1977 to 1986, after which it was largely replaced by the NVC. Although there is a broad correlation between these two classifications, there is not a one-to-one relationship (Cooke & Kirby 1994).

1.1.9 Shimwell Urban Habitats: The need for more detailed information on practically all wildlife habitat sites in urban areas results in the need for Phase 2 survey to cover virtually the full extent of the Phase 1 survey, in terms of both the number of sites and the range of habitats. Urban Phase 2 survey is therefore usually a relatively comprehensive multi-habitat survey and may be carried out either concurrently with the Phase 1 survey or as a follow-up after completion of Phase 1. Up to the present, most urban Phase 2 surveys have been based on a Conspectus of urban vegetation types devised by Shimwell (1983). This describes and classifies some 160 different plant communities of urban habitats, but some users have found it necessary to add to this list.

1.1.10 Vegetation communities of British Rivers: The Vegetation Communities of British Rivers is a revised classification based upon the composition of aquatic plant communities in rivers. It comprises three different levels of classification: (i) River Groups. This highest level consists of four distinct broad groups (ii) River Community Types. This second tier of division comprises ten River Community Types and (iii) Sub-types. This final sub-division includes 38 river sub-types.

1.1.11 UK Land Cover Map: Land Cover Map 2000 records terrestrial and inshore examples of widespread 'Broad Habitats'. The Habitats are elements in a classification designed for monitoring and maintaining biodiversity under the UK Biodiversity Action Plan. In practice, LCM2000 identified 16 Target classes (Level-1); it subdivided these into 27 Subclasses (Level-2). The subclasses included a variety of cover components (Level-3).

1.1.12 The Use Classes Order (UCO): The *Use Classes Order (UCO)* is used to classify use of buildings or other land for the purposes of section 22(2)(f) of the Town and Country Planning Act 1971 which specifies operations or uses and changes of use which are not regarded as involving development and therefore do not require planning permission.

1.1.13 National Land Use Database (NLUD): The *National Land Use Classification (NLUC)* was developed during the early 1970's by a team drawn from central and local government with the aim to devise a standard land use classification for new style development plans introduced by the Town and County Planning Act 1968. Legislative substance was provided by Department of Environment (DOE) Circular 71/74 which requested annual returns on land use change from local authorities classified into the 15 major orders of the NLUC. However the slow and incomplete response led to this exercise being abandoned in the late 1970s.

A modified version of the NLUC formed the basis of the *Land Use Change Statistics (LUCS)* classification developed by DOE in the early 1980s. The classification was designed for recording land use change by Ordnance Survey (OS) field surveyors during the course of map revision. It is a hybrid classification that comprises land use and land cover categories. Since 1985 the LUCS classification has provided the basis for recording land use and land cover change derived from OS mapping and is used in the preparation of annual statistics by ODPM.

A final modification of the NLUD was finalised in 2005 The resulting nomenclatures for use and cover have been

specifically designed to provide a system for classification and reporting that is appropriate to the national level.

1.2 Land Cover and Land Use European classifications

1.2.1 EUNIS Classification: The EUNIS classification is a comprehensive pan-European system to facilitate the harmonised description and collection of data across Europe through the use of criteria for habitat identification; it covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine. EUNIS data are collected and maintained to be used as a reference tool or dataset: for assistance to the NATURA 2000 process (EU Birds and Habitats Directives) and coordinated with the related EMERALD Network of the Bern Convention, for the development of indicators (EEA Core Set, Bio-IMPS, IRENA) for environmental reporting connected to EEA reporting activities

1.2.2 CORINE Biotopes Project Habitats: The CORINE Land Cover Map for 2000 (CLC2000) is produced jointly by the European Commission and the Member States and is an update of a similar map produced for 1990. CLC2000 is designed to be used at a scale of 1:100,000 and has a minimum mappable unit of 25 ha. It records 44 land cover and land use classes which represent the major surface types across Europe.

1.2.3 EU Habitats Directive Annex I : The main aim of the EC Habitats Directive is to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species at a favourable conservation status, introducing robust protection for those habitats and species of European importance. The 189 habitats listed in Annex I of the Directive and the 788 species listed in Annex II, are to be protected by means of a network of sites.

1.2.4 Geoland classification : Geoland is a multi-purpose Land Cover data and is the basis for a multitude of applications in environmental management and spatial planning. Hence, the Geoland Core Service Land Cover (CSL) serves the Geoland regional Observatories and a number of national level user organisations with harmonized, topical and geometric correct basic information on Land Cover. The CSL Land Cover database has been designed to easily plug in additional objects (thematic classes) and/or increase the minimum mapping unit, as needed.

1.2.5 LUCAS classification: The LUCAS classification system was established by applying best practise for the construction of land cover and use classifications, as recommended in Eurostat "Manual of Concepts on land use/cover" (Eurostat 2000). The land cover classification is defined in 3 hierarchical levels of detail with 57 classes at the 3rd level, and the land use nomenclature is distinguished in 14 classes at the 3rd level.

Most of the European classification systems are an attempt to standardize land cover and land use nomenclatures across countries for the compilation of an European inventory of land covers and land uses. However, at practical level this has created a two tier classification system in most countries where the different classification systems are still in place and further

classifications are created or compiled from existing ones to report to European institutions or programs.

2. LAND COVER AND LAND USE NATIONAL FRAMEWORK

As the previous section illustrates, the provision of land cover and land use information is varied, partitioned and most of the time focused on specific purposes. In Land Cover a big proportion of the existing classifications are vegetation classifications, broad land cover classifications, or systems related to the description of a specific feature. Thus, they are limited in their capacity to define the whole range of possible land cover classes (di Gregorio, A. and Jansen L., 2000). Land Use classifications seem to be less common or less published but equally customised to user requirements.

From the point of view of National Mapping Agency, instead of creating yet again a new classification that claims to be the best suited to the majority of users maybe the question is how to create a framework that can incorporate all the classifications that already exist so that the user can choose, analyse and visualise the information as it is most suited for their purposes. This is of course very difficult to achieve. Ultimately all classification systems are applied to phenomena that they define in the real world, and where these phenomena differ it may be impossible to always incorporate different systems. Different ways of classifying vegetation may for example result in the emergence of areas that overlap. However, when considering classification systems the tendency is to think in terms of simple hierarchies, but an ontological approach enables classifications to be built in more complex ways than simple subsumption hierarchies. We argue, that whilst such an approach still cannot achieve total resolution, it offers a much better and more flexible approach that should be capable of dealing with the majority of cases and allowing users to adapt the system to their own needs.

One way of creating this framework is to define geographic space as geographical objects, their attributes and relationships (Nunes, 1991). This is an object oriented approach that very much suits the structure of Ordnance Survey data. Each Feature in OS MasterMap® has a primary topographical classification into a descriptive group. The feature is assigned to one or more of 21 groups most of which are categories of real world topographic objects such as Path, Building or Natural Environment. A Descriptive Term gives further classification information about the feature. For example an area feature can have a descriptive group with value Natural Environment that can have one or more descriptive terms specifying the natural land cover types present in the area (OS MasterMap user guide v2.0). Apart from this attribution, MasterMap offers an Address layer and Integrated Transport Network layer (ITN) that provide more attribution related to the use of those geographical features. There is also imagery that forms an Imagery layer that could aid land cover information (although this imagery would have to be processed in a different way that is currently is to take advantage of infrared data).

However there is no relationship established between these attributes or between different layers. Descriptive groups encompass feature classes as well as feature geographic shapes and the group of descriptive terms is also a mixture of attributes that are not grouped in a consistent manner. A descriptive term could include anything from a rock or a top of a cliff to an

electoral or district division. At the moment there is no automatic conversion of addresses or ITN features into land uses or integration of derived information from remote sensing sources. There is a need for content specification of the data in terms of land cover and land use that is currently not in place.

In order to have a clear internal structure of land cover and land use information there was therefore a need to develop an ontology that could establish links and associations. This ontology was developed in the Protégé environment. In the ontology a high level set of classes were created for both land cover and land use and relationships established with each other. It was important to clearly define the different nature of land use and land cover classes as they are normally mixed up in many of the existing classifications. For example, the NLUD land cover classification included classes such as agricultural land or features such as roads and pavements and the land use includes water and open land. Also CORINE land cover classification includes industrial, commercial and transport units as well as mine, dump and construction sites. So a clear definition of terms and relations is obviously needed.

The integration of this ontology within the framework follows the suggestion of Fonseca et al (2000). They suggested an inheritance structure by which we define general classes that contain the structure of a generic type of object and then specialise these classes into subclasses. The subclasses would inherit all the properties of the super-class and add some more of its own. In this way the combined use of objects and ontologies could provide a rich model to represent geographic entities. It also allows us to provide a sensible relationship between land cover and land use in order to help define topographic objects. For example by knowing that the land cover for a “field” is “trees” and also knowing that the land use is “fruit production” then we can deduce that a more specific classification for the area of land is “orchard”. Similarly if we know that an object is classified as an orchard that it must have land cover of trees and its land use is “fruit production”. Also different users have different views on classes. With this framework they could use the main class as a common starting point and add their own subclasses that would inherit all the main properties of that class and serve their particular purpose. Figure 1 reflects this principle.

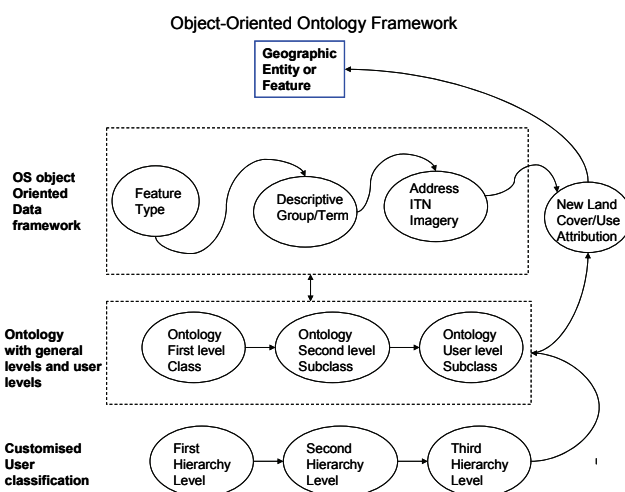


Figure 1: Object-Oriented Ontology Framework

The link between the object oriented structure of Ordnance Survey data and a user classification is done through the intermediate ontology that can translate or incorporate new attributes or subclasses that then can be added to the existing features. Ultimately this framework would allow having automatic customised legends for bespoke maps.

3. BOURNEMOUTH CASE STUDY

3.1 Data and methods

A preliminary trial was focused on the centre of the urban area of Bournemouth (south of England). The framework was used as guidance as there was still not an automatic transformation devised for the trial. The data used for both land cover and land use comprised:

- MasterMap Topography layer
- MasterMap Address Layer 2
- Mastermap Integrated Transport Network (ITN) layer
- Aerial imagery acquired in June 2006, 4 band spectral resolution and spatial resolution of 60 cm.

The customised user classification included in this trial was the NLUD classification.

3.1.1 Land Cover: For the Land Cover classification we used a combination of the layers described above. The ITN layer was used to identify artificial non-build up surfaces whereas the Topography layer did so for artificial build-up areas. For the classification of natural surfaces there was some information available on the Topography layer but the attribution was not rich enough to create a complete classification. So it was a classification from aerial photography that provided the most useful information. The classification consisted of a combination of texture, NDVI and height data that helped to identify high vegetation (trees) from low vegetation (shrubs and grass) and bare surfaces using a Maximum Likelihood classifier in Erdas Imagine.

3.1.2 Land Use: For the Land Use classification Address layer 2 provided basic information about uses in different addresses. ITN layer provided information about transport uses. Topography layer and aerial photography were used to assess whether there were any morphological or visual signs that could help distinguish different areas within the urban space (residential, services, industrial, green open space, etc)

3.2 Results

The Bournemouth trial highlighted different issues for Land Cover and Land Use.

A Land Cover classification that uses the general classes defined in the ontology could be quite straight forward using the data sources available. However this information could be insufficient depending on the level of granularity of other classifications. Also it has to be taken into account that the land cover classification of an urban environment is less complicated than that of a rural environment. The link between the ontology general classes and the NLUD classes worked well. However,

the ontology classes allowed for more flexibility than some of the very specific NLUD classes.

Land Use was a much more complicated subject. The link between the NLUD classification and the classes in the ontology did not present major problems. However, when it came to the actual classification using the data available there were a high number of polygons with unknown land use. Also, the diverse nature of land use meant that some polygons had several potential numbers of uses which could complicate the management and display of information for those using a detailed classification. Granularity is therefore an issue.

There was a clear aid from aerial photography to distinguish residential areas from other that could be categorised as commercial or industrial buildings. It also helped to identify uses such as hospitals or schools and verify some land covers such as sand or scrub. However this assessment was done manually. More research is needed to investigate the possibility of an automatic way of identifying these areas.

3.3 Discussion and further work

The results from the trial in Bournemouth highlighted the following issues:

- Need to assess other data sources. There are a few sources of ancillary data that could help complement the information that OS already hold. Some of them could come from directories such as Thomson, Yell, Experian and Valuation Office. One of the problems with these directories is that their information is generally not georeferenced. A test matching some of these directories to references on the ground achieved a 60% success. However it proved to be very time consuming.

- Need to assess other methods of data capture. (i) Web harvesting. We performed a trial on web harvesting to complement and validate the information held by Ordnance Survey. The first obstacle are legal constraints on use of the data which meant 80% of all sites could not be harvested. Furthermore, it is usually difficult to find out the currency of data provided in the web. The conclusion from this study was that automatic web harvesting is not suitable for land cover and land use information. (ii) Other sources of data capture to consider are surveyors and video surveying. Surveyors are used daily by Ordnance Survey to record changes in OS Mastermap layers. We have to explore the way of taking advantage of this resource so that they record land cover and land use information at the same time. A video capture trial is planned for this summer (iii) Automatic capture of land uses using aerial photography. The main objective of this assessment would be to determine what can be classified and in which way this information could complement that collected through other sources.

- Need for user feedback. We need to know whether this approach answers any of the current or future land cover and land use user's needs and could be a way of integrating different datasets.

In conclusion, the design of an object-oriented ontology framework for land use and land cover that provides a high level classification seems like the right approach in order to provide a starting point and place of agreement for different users. However, there is still a lot of work to do in terms of data

capture, data storage and maintenance, linkage with other widely used classifications and the understanding of user needs.

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