

# Creating Spatial Information: Commissioning the UK Land Cover Map 2000

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## Abstract

Environmental datasets are subject to ontological differences in the way that information is recorded and reported. One of the implications is that environmental monitoring and the identification of loci of change is difficult. This generic problem is explored with reference to land cover mapping in the UK. The decennial land cover projects (LCMGB and LCM2000) are introduced and their differences described. Their different scientific, policy and commission contexts contribute to the overall change in methodology. Increased user participation in the specification of the 2000 dataset is the result of structural changes in the way policy is conducted. The Broad Habitat classification system was determined by many factors and not solely the responsibility of the scientists producing the data. The drive to integrate data that have fundamentally different characteristics and properties is examined and the botanical background to one dataset being used to provide quality measures for another is described. The value of combining two fundamentally different approaches and presenting them as an integrated product may be misleading. Each survey offers a different approach in terms of the spatial detail, extent and data primitives that are recorded.

**Keywords:** ontology, integration, Land Cover Map 2000

## 1 Introduction

There is a generic problem of discordance faced by workers seeking to integrate different spatial data which at least seem to report the same or similar information (Fisher, 1999). This can be exemplified through land cover. Many different datasets provide information about land, land cover and vegetation. It is often difficult to translate or relate the information contained in one dataset to that of another, despite the fact that they record similar thematic attributes and are spatially or temporally coincident. This is because surveys are subject to different

methodologies, even when they are repeated or updated. Whilst more accurate recording of environmental features during an inventory is important, often we would like to be able to address specific aspects such as monitoring change or to make more informed decisions based on sound environmental information. These objectives are hindered by the difficulty in translating and relating the information captured in *Survey1* to that captured in *Survey2*. This problem is typical of very many spatial databases. Two major issues are entwined in this problem, the first is the technical methods by which the information may be translated, and the second is the institutional-social conditions that cause it to happen.

We explore this generic problem with reference to land cover mapping in the UK and in particular to the Land Cover Map of Great Britain (LCMGB) produced in 1990 and the UK Land Cover Map 2000 (LCM2000) produced a decade later<sup>1</sup>, both derived from satellite remote sensing. These two surveys provide country-wide inventories of land cover for a range of activities and a large number of end users. Whilst there is much interest in the change detection and environmental monitoring, the stated objectives of LCM2000 are to “provide an enhanced product, rather than pursuing the measurement of change through a direct repeat of the LCMGB” (Fuller *et al.*, forthcoming). However, the fact is that both products are called the “Land Cover Map” (LCM), this suggests to users that LCM2000 is the second in the series, in spite of methodological differences in how the information was derived and presented.

In this paper, we document the process of commissioning the datasets, and the resulting uncertainties produced by a shift in ontologies consequent to many developments especially a change in policy context. We demonstrate that one contribution to this uncertainty in spatial information is embedded in the socio-political process of creating the data.

## 2 LCMGB and LCM2000

The 1990 LCMGB recorded the stock of land cover across the country and details can be found in Fuller *et al.* (1994). The LCMGB raster dataset was the first complete high-resolution survey of the land cover of Britain to be mapped from satellite imagery. It was produced using a per pixel supervised maximum likelihood classification (MLC) of Landsat Thematic Mapper data with a derived pixel size of 25 x 25 m, recording 25 “Target” land cover types. LCMGB was financed by the British National Space Centre and NERC with funds from the Department of the Environment (DoE, later DETR). It provided a demonstration of the viability of using satellite imagery, and was incorporated into a wider umbrella project, the Countryside Survey 1990 (CS90; Barr *et al.*, 1993). CS90 included a sample-based field survey of detailed vegetation composition and land cover among other data from 508 1km<sup>2</sup> squares. The field survey and the LCMGB

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<sup>1</sup> Note GB is Great Britain, and includes England, Scotland and Wales, while the UK (United Kingdom) includes these countries as well as Northern Ireland.

were both produced by CEH (the Centre for Ecology and Hydrology, then known as the Institute for Terrestrial Ecology, ITE).

LCMGB was the first inventory of England and Wales since Coleman (1968), and of GB since Stamp (1939). The value of the LCMGB survey is illustrated by the extent to which it has been used in many and various applications. LCMGB data have been supplied under license to ~500 academic, policy and commercial users, with some 300 further users of more generalised data through the Countryside Information System (Haines-Young *et al.*, 1994). Its use and application has been reported in a variety of academic papers.

LCM2000 represents a significant methodological departure from LCMGB. It combines a parcel-based supervised MLC with ancillary geographical data and records land cover information in vector format rather than raster (pixel). Vector format was to increase structural integrity by applying methodological developments made through CLEVER-Mapping (Smith and Fuller, 2001). In addition, it allows attributes to be attached to the parcel (Smith and Fuller, in press) LCM2000 provides an enhanced product, i.e. with explanatory meta information, and increased thematic detail. A knowledge-base of about 600 rules (Knowledge Based Corrections; KBCs) were developed under the method proposed by Groom and Fuller (1996), and applied to parcels that were classified with low confidence and / or with classes out of their natural context (Fuller *et al.*, forthcoming). Extensive parcel attributes describe class probabilities, within parcel heterogeneity, and each parcel's processing history, as well as recording the parcel's land cover class. LCM2000 is distributed as part of the Countryside Survey 2000, (CS2000) which includes a field survey of 569 1km<sup>2</sup> sample locations. Further details about LCM2000 can be found at <http://www.ceh.ac.uk/data/lcm/LCM2000.shtm>

### 3 LCMGB Issues

The aim of this paper is to illustrate the generic problem of ontological changes that occur as the understanding advances in a science that supports a process of national inventory, and to describe the origins of such change. The value of LCMGB, as the first census survey of the land cover of Britain, cannot be overstated and is reflected by the number of end users, applications and reported academic investigations. A number of themes emerged post LCMGB and in the cycle of reports and papers, that inevitably accompany such an important undertaking:

- Integration LCMGB information with the field survey component of CS90;
- Lack of understanding in *some* less technically informed users about the limitations of maps in general, and by-pixel classification, in particular;
- Reviews of CS90 and recommendations for a future CS2000.

### 3.1 Integration of Field Survey and Satellite Map

In 1993, the field survey data and the LCMGB were presented as part of an integrated project CS90 (Barr *et al.*, 1993). Comparisons of the land cover information showed them to be different (Wyatt, *et al.*, 1993; Fuller *et al.*, 1998). For instance, the satellite derived LCMGB recorded the area of the key cover type “Open shrub heath / moor” as 8% of the country while the field survey identified 5% (Fuller *et al.*, 1998: Table 7, p.113). This is an inevitable consequence of the different methodologies. Studies that have compared the two approaches such as Cherrill *et al.* (1995), Fuller *et al.* (1998) and Wyatt *et al.* (1993), have consistently described differences due to:

- *meaning* (class labels and their nomenclature, in terms of class recognition on the ground, and spectral separability in the imagery);
- *timing of data capture* (effects of: different years, growth cycles, seasonal differences, and diurnal effects);
- *spatial factors* (scale, geo-registration, heterogeneity, boundary pixels);
- *statistical issues* (training data collection).

Wyatt *et al.* (1993) and Fuller *et al.* (1998) go to considerable effort to describe the origins of the different “answers” provided by the two approaches. They acknowledge the difficulty in defining any kind of “truth” in mapping and Fuller *et al.* (1998) comment on users failing to accommodate differences between maps.

### 3.2 Perceptions of LCMGB

The LCMGB does not capture the botanical detail of the field survey, but does provide a comprehensive survey covering all of Britain. The first thing many users of LCMGB did was to compare the data with their local knowledge (Andrew Stott, pers. comm.). The trade-off between an extensive and comprehensive survey is increased spatial and thematic generalisation, and in spite of local errors the database is largely correct, Fuller *et al.* (1998) comment that “spectral misclassification caused most of the errors in the Land Cover Map” and “might have been removed with more sophisticated knowledge-based procedures” (p123).

As part of CS90 objectives, information from the field survey and satellite land cover maps were compared. This comparison was used to provide a measure of thematic quality for LCMGB whilst stressing the lack of “truth” in mapping and the nature of different classifications. The user community, however, found the descriptions of LCMGB quality based on a comparison with the field survey confusing (Haines-Young and Swanwick, 1996; Wyatt *et al.*, 1993).

Better-informed users, who could view the dataset through “Thematic Mapper Eyes”, were able to understand the data and accommodate these errors much more easily than others (Neil Veitch, pers. comm.). They were able to appreciate the value of LCMGB due to its spatial extent and used it to provide a first cut for directing more detailed user activity resulting in targeted efforts and further analyses.

### 3.3 Reviews of CS90 and Recommendations for CS2000

Reviews of CS90 have noted the issues raised by integrating information from the field survey with that from the satellite map (Fuller *et al.*, 1998; Haines-Young *et al.*, 2000). Most of the differences between the two approaches reflect the different paradigms or views of the world embodied in them. Others are more subtle, such as the confusion between land cover and land use. The field survey often recorded the land *use*, whilst the LCMGB necessarily recorded the dominant *cover*. For instance, juvenile trees were recorded as “woodland” in the field survey and as the understory vegetation in the LCMGB (Fuller *et al.*, 1998).

Some of the perceived discrepancies reflect the fact that the two surveys were rolled together after their inception, rather than being planned and designed together. LCMGB was a demonstrator project. The independence of the surveys is illustrated by the names and meaning of the land cover classes they use. For instance, the reporting of the land cover stocks was for 59 *Reporting Classes* in the field survey and 25 *Target Classes* in LCMGB, and they employed different definitions (Wyatt, *et al.*, 1993). The classes did aggregate to a common classification of 17 classes, however.

Recommendations for the proposed repeat land cover map LCM2000 concentrated on the discrepancies between the field survey and the satellite data (e.g. Fuller *et al.*, 1998: p123, state that “there is likely to be inconsistency if one is used to validate the other”) and the issue of better integration. For instance, amongst many points Fuller *et al.* (1998) conclude their paper by saying: “A planned update in 1998-2000 will address many of the problems of the CS90, will upgrade the detail and accuracy and will ensure even closer integration between the field and satellite surveys.” (p125).

## 4 Policy Background for LCM2000: A Changed World

The policy climate within which national environmental monitoring efforts were taking place had changed considerably by the mid 1990s. This was due to: the Earth Summit in Rio in 1992 (Secretariat on the Convention on Biological Diversity, 2000); European Union *Habitats Directive* 92/43 (CEC, 1992); “*Biodiversity: the UK Action Plan*” (BAP) (UK Biodiversity Steering Group, 1994).

The Convention on Biological Diversity (Article 7) requires that each country identifies and monitors national components of biodiversity. The EU Habitats Directive promotes the maintenance of biodiversity and demands that surveillance, identification and monitoring of the natural habitat and species be undertaken (Article 11). The UK BAP was implemented as a result of these commitments. UK legislation delegates the duty of implementing the Directive to all organisations and agencies that have or could have an impact on the areas designated under the Directive. This was a significant increase in the role of environmental agencies and the legislation emphasised the role of locally prepared

management plans. In this context there were specific references to the potential role of and modifications to initiatives such as the Countryside Survey series whose “repeat surveys provide a mechanism for monitoring the biodiversity of the wider countryside” (UK Biodiversity Steering Group, 1994: 9.19).

## **5 LCM2000**

Land Cover Map 2000 was undertaken within the umbrella of the CS2000 (Haines-Young *et al.*, 2000) to update and upgrade LCMGB. It sought to provide an enhanced survey and aimed from the outset to be a complete revision rather than a repeat using the earlier methods (Robin Fuller, pers. comm.). To this end, an improved vector based methodology was adopted. It is possible to delineate two distinct spheres of influence, firstly a drive for “better” science and secondly a demand for policy relevant map products.

### **5.1 Scientific Influence**

The objective concern of most scientific research in the Cartesian tradition is greater certainty and understanding through the application of scientific reason in an objective manner in order to better explain and predict. In the LCM2000 project this activity can be seen in:

- The development and adoption of improved techniques in LCM2000 using technological developments made in CLEVER-Mapping (Smith and Fuller, 2001). Using a parcel representation allows processing history and heterogeneity attributes to be attached to the parcel;
- Application of the lessons learnt from the previous LCMGB. One of the key issues to emerge from the LCMGB project was the problem created by the fundamental differences between the field survey and satellite map. To this end explicit statements about improved methodological integration had been made as the LCM2000 project was beginning (Fuller *et al.*, 1998).

The nature of these influences are implicit in most academic scientific activity, where improved answers are sought by applying the lessons learnt from previous exercises and by developing new techniques.

### **5.2 Policy Influence**

The second sphere of influence on the LCM2000 project was the increased role of policy as exercised by external agencies. Here a number of inter-linking factors combined:

- The devolution of direct responsibility for local environmental monitoring away from government to environmental agency accountability;

- The links to policy were explicit in that the stated objectives of CS2000 were to enable the UK to fulfil its international obligations to monitor biodiversity;
- The concept of Broad Habitats within which biodiversity monitoring could take place. These provide the framework within which the UK seek to meet their *Priority Habitat* obligations and were specified by governmental departments and agencies funding the LCM2000 (Fuller *et al.*, forthcoming);
- The increased role of environmental agencies such as English Nature and the Environment Agency. They were legally required to fulfil national policy objectives locally.

### 5.3 Broad Habitats

The two spheres of influence came together in the LCM2000 steering group. The steering group played a much more active role than its predecessor in 1990.

The LCM2000 steering group was constituted from potential users who had increased policy obligations and data producers with improved scientific knowledge. The agencies wanted information about Priority Habitats, but the scientists did not believe that these could be mapped directly from remotely sensed imagery. In the end, a compromise was made to try to map Broad Habitats, even though the scientific view was that some of these could not be mapped directly.

The steering group had the unenviable task of balancing the policy desires of the agencies with the expert scientific knowledge of what features could be reliably determined by their reflectance characteristics. The remote sensing paradigm requires that identifiable features have distinct spectral characteristics, but many of the Broad Habitat classes do not have distinct spectral signatures. This problem was compounded by the late delivery of formal Broad Habitats definitions in the overall CS2000 project (Jackson, published in July 2000). Both the field survey and land cover map projects had to use their own *working definitions*. Nonetheless, the customer's wishes were accommodated, which was a time-consuming exercise as it meant identifying thousands of spectral classes, which were aggregated into class Variants, Subclasses and ultimately Target classes. Broad Habitats were constructed from these. In order to meet requirements of the steering group external data were obtained and used particularly for grassland and bog covers.

The result was that the specification of the LCM2000 could be seen to be driven by two general influences: science and policy. The satisfaction of both of these influences resulted in a compromise between what was scientifically possible and what was politically desirable.

### 5.4 Integration in the Production of LCM2000

One of the themes arising from CS90 that was the focus of much work was the need for the field survey and land cover map components to be better integrated in

CS2000. Integration can be addressed from many positions, for instance spatial factors, meaning, timing and statistical issues. Some of these are easier to address than others. However, other differences are fundamental to each technique and their integration may be irreconcilable. This section explores integration from the thematic perspective of land cover reporting.

At one level, greater integration is illustrated by the reporting of land cover stocks in terms of Broad Habitats, using a set of similarly defined and labelled classes. Examination of the definitions of the Broad Habitat classes used by each approach shows that the classes are described similarly, principally on their botanical and bio-geographic properties. Descriptions can be found at:

[http://www.cs2000.org.uk/Report\\_pdf/appen.pdf](http://www.cs2000.org.uk/Report_pdf/appen.pdf)

<http://www.ceh.ac.uk/data/lcm/lcmleaflet2000/leaflet3.pdf>.

However the nature of data capture in each approach is fundamentally different in terms of the data primitives recorded by the field survey as compared to the land cover map. Necessarily the Broad Habitats identified by LCM2000, were defined by their spectral and reflectance properties, rather than their botanical ones. The field survey by contrast records features based on their botany and ecology such as species composition and number. These differences are important when trying to present information of thematic equivalence from the two components.

To address the differences in perception, staff preparing the LCM2000 attended a training exercise in the field with the field surveyors of the CS2000 to develop a shared understanding of land cover concepts.

The steering group for LCM2000 was much more active as a forum for decision making than was its predecessor. Indeed the advisory group for LCMGB was perceived by some not to have existed because: the data and approach had been determined before the group had been formed. For LCM2000 there was increased explicit dialogue between users and scientists before the survey was started and the nature of involvement of these stakeholders was different (come to that the word stakeholder had been invented).

The LCM2000 steering group, typical for a large publicly funded exercise, was set up by the government (DETR). The initial objectives were to gather financial support for production and to drive the LCM2000 project towards policy. The LCM2000 steering group had other roles: it provided a forum by which user specifications could be articulated and solutions to problems could be discussed, and most importantly the existence of a steering group demonstrated that the project had wide support. This in turn allowed the development of a collection of possible funding organisations under the aegis of the steering group. The need for answers to different questions to those in 1990 resulted in different specifications. There is some difference in opinion about the precise role of the LCM2000 steering group in resolving issues of specification and approach. Steering group members experienced different degrees of involvement in the decision making process. Some thought that they exercised influence over decisions; they were able to modify the specification to enable them to make some use of the outputs in support of the advice that government seeks from them. Others believed that by



the time the steering group was formed, scientific decisions about specification and data had already been made, and that therefore their role was to rubber stamp these decisions.

## 6 Discussion

The preceding sections have shown the origins of difference between surveys: scientific development, applying lessons learnt from experience and the impact of national and international policy. The resultant methodological change common to many repeated national inventories: the previous project is implicitly supported by the desire for a repeat, and scientists will always try to improve their methodology.

The use of the Broad Habitats, defined primarily by their botany, illustrates the strong influence of policy on the LCM2000 project. Broad Habitats were agreed as the reporting classes for both components of CS2000. However, there were greater difficulties in defining these classes using the relatively coarse satellite image data compared to the finer granularity of information captured by the field survey. For the field survey there was considerable post survey work, such as the ECOFACT series (Bunce *et al.*, 2000), which established that it could deliver information in terms of “Broad Habitats” as demanded by policy. Roy Haines-Young (pers. comm.) stated that the field survey had “learnt to speak the language of policy and [so] got funded”. In contrast, despite having many hundreds of applications and end uses, the land cover map did not have the equivalent to the ECOFACT work.

Umbrella projects, such as the Countryside Surveys of 1990 and 2000, seek to present a unified message from rolling together the two different world views embedded in the Land Cover Map and the Field Survey. This can be confusing and result in tension if one approach is presented as implicitly “better” than the other. If policy demands are being satisfied by the field survey *and* satellite land cover map then the assumption is that both approaches are providing a meaningful resource inventory. The description of LCM2000 shows an attempt to accommodate the “ecological view” as embodied by the field survey. There is no equivalent to assess the field survey in terms of the remote sensing view of the world. Thus, there is an implicit assumption that field survey paradigm is superior. The official integrated product will probably be released in the next couple of years, until then users will have to accommodate different approaches in terms of the spatial detail, extent and data primitives that are recorded.

The origins of dataset differences between LCMGB and LCM2000 can be attributed to one of three general types: data capture, information reporting and representation, and in labelling semantics. The reasons for the methodological changes within time series land survey projects may be scientific (technological and scientific developments) or political. That is to say, that changes in the political and social context within which the survey is being commissioned means that the questions to which answers are being sought are different. One of the net

results of changing the question is to reduce the capacity to track changes over time.

Standardisation, is frequently cited as a panacea to inter-operability, but misses the point that different users have different objectives at different times, in different institutions. Presenting users with a single land cover database assumes an homogeneity of interest that does not exist. Alternatively, presenting the user with the raw data in a standardised way is also problematic: it assumes users have the technical skills to construct their own models. This is not the case, different users will create similarly named land cover features that are in turn assumed to mean the same thing, and the problem expounded in this paper persists.

The UK Land Cover 2000 dataset seeks to address this paradox by including extensive attributes at the polygon level. These allow the user to apply specific local analyses without having to assume that the data quality is evenly distributed. The philosophy of the production team has been to explicitly retain and report as much information as is feasible, by publishing meta-information about the polygon processing history and the top 5 spectral sub classes within the parcel. However, due to changes in approach the LCM2000 comes with an explicit warning against the direct measurement of change. This is essential, as users will compare their local knowledge with the LCMGB and LCM2000 datasets.

## **7 Conclusion**

We have documented the changing pressures on the development of a land cover map of the UK, in its decennial reporting in 1990 and 2000. The changes in policy between those dates have made one contribution to the dissimilarity in the products and the changing methodology has made another, providing tensions between what is technically possible, organisationally expedient and scientifically objective. The two land cover activities of the CS2000 have so far had limited integration, despite persistent identification of the problems of integration post CS90. The majority of the integration has yet to take place and is about to start as we write in March 2002, some four years after data capture began.

Although the specific case we document here is unique to the Countryside Surveys, we believe that the general situation is typical of major inventory initiatives. Such initiatives are funded from the policy realm and have to respond to changing policy priorities. They are costly and therefore have to bow to the dictates of policy. From a technical point of view, the net result is that although the names of the land cover maps announce their similarity (Land Cover Map of Great Britain and Land Cover Map 2000), even if both were perfectly correct for the whole country, any comparison between them to establish landscape change is fraught with uncertainty because of the changed class definitions (ontologies) and methodology.

The endemic problem indicated by the case of LCM2000 is not overwhelming: we believe that it can be overcome by applying methods developed around the notion of establishing formal relations between datasets (either semantic or

statistical) and then using formalisms (probabilistic and qualitative) to model the uncertainty at the level of the polygon. These are being tackled within the REVIGIS project. We would urge land cover data commissioners and producers to follow the example of the CEH and LCM2000 to include some level of process history and indications of thematic heterogeneity as part of their standard products.

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