Geospatial Land-use Classification for New Zealand: Review and Recommendations

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Abstract

This project examined theoretical and practical approaches to land-use classification to support development of a geospatial land-use classification for New Zealand. Land use refers to the modification of and related activities on the land by people to sustain human life. We allocate and change land use to produce different combinations of goods and services in response to changing human needs and wants. Some changes are temporary, for example, crop rotation, while others are more permanent, for example, urbanisation. Also, some consequences of land-use change or associated practices are easily observed, for example, forest harvesting, while others are not, for example, gradual loss of soil fertility through inappropriate management. Given that New Zealand currently lacks nationally consistent and comprehensive geospatial land-use information, developing a geospatial land-use classification would help fill that gap by 1) meeting a range of needs, 2) helping underpin policy, planning, and resource management, and 3) contributing to reporting on progress towards sustainable development across scales within New Zealand.

Land-use classification broadly falls into four types along a gradient from simple to complex. Categorical approaches depict land use as discrete classes with no relationships among them. Hierarchical approaches depict land use as a nested set of classes. Higher level classes, for example, urban, become divided into more specific classes, for example, residential, commercial. Multidimensional approaches store multi-attribute information for defined unit areas and allow recombination to generate different land-use classes. Semantic classifications derive from linguistic theory and describe land use using a rich collection of words and formal grammar from which different interpretations (ie, classifications) could be derived. International practice strongly favours the use of hierarchical classifications, and many countries have adopted official hierarchical land-use classifications. A few examples (for example, SIOSE from Spain, American Planning Association) take a more multidimensional approach. Regardless of the approach, most land-use classifications internationally remain unimplemented or partially implemented. In New Zealand, there have been four attempts to develop a land-use classification. None of these became officially adopted, although current land valuation practices include an unofficial land-use classification system. Our results suggest New Zealand would benefit from adopting a semantic approach to land-use classification. Such an approach appears the most promising, given its ability to include a diverse range of information, to incorporate new information as it becomes available, and to generate a range of classifications, including reference or official classifications, to meet a variety of needs while retaining the capacity to translate and compare among them.

Keywords

Categorical, classification, geospatial, hierarchical, land cover, land use, land-use activity, land-use change, semantic, multidimensional, New Zealand.
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1 Introduction

Background
The allocation and use of land affect all aspects of New Zealand’s overall well-being (cultural, economic, environmental, and social) and quality of life. Land use can be defined as the activity(ies) or socio-economic function(s) for which land is used, and the same land can support multiple uses. It differs from land cover, which describes the physical state of the land (Lesslie 2004). Land-use statistics provide information on the function and purpose for which land is currently used and, if tracked over time, how land use changes (Young 1998). Appropriate land-use information requires consideration of three interrelated aspects or dimensions: information, space, and time. Different data sources provide different types of land-use information at different spatial and temporal scales including, but not limited to, satellite imagery, aerial photography, ground surveys including direct sampling, and surveys of land-use managers.

New Zealand currently lacks any nationally consistent and comprehensive land-use information covering the full range of natural, production, and urban landscapes. The provision of such information would help meet critical gaps in land-use planning and policy and resource management, improve monitoring and reporting of land use and land-use change, and foster better outcomes at national (eg, carbon monitoring, biodiversity protection), regional (eg, Resource Management Act), and district/city (eg, land-use planning) scales. It would also provide key information leading to more effective national (eg, State of Environment, Economic and Social Statistics) and international (eg, OECD, System of Environmental Accounts) reporting on New Zealand’s progress towards more sustainable development.

A standard and consistent approach to land-use classification at the national level would improve the quality of data collected and provide a framework for a harmonised approach. Ideally, this would lead to the development of a national land-use information base.

Purpose
This review helps fill a crucial information gap by providing a solid theoretical and practical comparative foundation for developing a New Zealand geospatial land-use classification that could meet a range of information needs. Such a classification would be used in land-use mapping and land-use change analysis to underpin policy, planning, and resource management, and to contribute to reporting on progress towards sustainable development at a number of scales within New Zealand. A land-use classification would complement (not replace) the existing classifications of land cover found in the national Land Cover Database (Thompson et al 2003). In fact, robust, detailed, and accurate information on both land use and land cover, as well as land tenure, are needed to inform a range of existing and emerging cultural, economic, environmental and social issues within New Zealand.
**Anticipated outcomes**

Development of a land-use classification would contribute to improved geospatial land-use and land-use change information for New Zealand by providing enhanced, geospatial statistics and information to support:

- OSS reporting on Tier 1 statistics
- Land Statistics Accounts
- State of Environment reporting at regional, national, and international levels
- Policy, planning, and resource management under the Resource Management Act and Local Government Act.

By enhancements, we mean a) greater statistical accuracy from improved land-use mapping, b) the ability to combine geospatial land-use information with other geospatial information to conduct more sophisticated analyses, and c) enhanced communication and education capability through the production and generation of maps and other visualisation techniques.

Improving a range of Tier I Statistics through the provision of land-use information at multiple scales will in particular provide enhanced land-use information for Agricultural Production and Environmental Impacts of Economic Activities, such as provision of statistics from a national overview to a regional glance on value of production by land use, relative area of land use, etc. This will in turn enable integration of OSS, economic, social, environmental, and cultural statistics to conduct analysis work, and to better tell the land-use stories of New Zealand.

**Methodology**

- Review international literature on land-use classification including various classification methods that meet multiple research and end-user needs.
- Review New Zealand literature on land-use classification including identifying any previous classification systems developed.
- Assess land-use information needs in New Zealand via an end-user survey.
- Based on the findings, provide recommendations for developing a geospatial land-use classification for New Zealand.
2 Conceptual models of land-use classification

Defining land use

In considering land-use classifications we must first consider what land use is or represents. In his introductory chapter entitled ‘New Directions in Land Use Classification,’ Guttenberg (1993, p26) wrote “This treatise is about one ambiguous planning term – land use”. The term is one we can understand and appreciate at a conceptual and even emotional level, but delineating a definitive boundary or formulating a concise definition leading to a robust classification of land use has proved difficult both practically and operationally (Duhamel 1998; Lesslie 2004; Mücher et al 1993). Further uncertainty and confusion often arise in understanding the difference between land use and land cover (de Bie 2000), so it is usually helpful to consider and define them together (Table 1). The distinction between land use and land cover is not necessarily absolute. In many classifications, land cover is treated as a de facto land-use class for reasons of expediency.

Table 1
Definitions of land use and land cover

<table>
<thead>
<tr>
<th>Source</th>
<th>Land use</th>
<th>Land cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and Agriculture Organisation (FAO)</td>
<td>The function or purpose for which the land is used by the local human population and can be defined as the human activities which are directly related to land, making use of its resources or having an impact on them (FAO 1995, 21–via Briassoulis, 2000).</td>
<td>The observed bio-physical cover on the Earth's surface (via De Gregorio &amp; Jansen 1998, Duhamel 1998).</td>
</tr>
<tr>
<td>Lesslie (2004)</td>
<td>This refers to the purpose to which land is committed, including the production of goods (such as crops, timber and manufactures) and services (such as defence, recreation, biodiversity and natural resources protection). Some land uses, such as cropping, have a characteristic land-cover pattern. These land uses frequently appear in land-cover classifications. Other land uses, such as nature conservation, are not readily discriminated by a characteristic land-cover pattern. For example, where the land cover is woodland land use may be timber production or nature conservation.</td>
<td>This refers to the observed physical surface of the earth, including various combinations of vegetation types, soils, exposed rocks, water bodies.</td>
</tr>
<tr>
<td>de Bie (2000)</td>
<td>A series of operations on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources.</td>
<td>The observed (bio-) physical cover on the earth's surface (from FAO 1997).</td>
</tr>
</tbody>
</table>
Types of land-use classifications

Much effort has been spent on developing land-use classifications in the past century (Duhamel 1998, Guttenberg 1993, Lesslie 2004, Mücher et al 1993, Scace 1981). In considering the different types of classifications, it is important to distinguish between the information contained in the classification versus the structure of the classification. For our review we focus primarily on structure, rather than information.

Most land-use classifications appear to share a similar design philosophy characterised by a variable information scale represented by some form of information hierarchy. It was difficult to determine from the literature the reasons for the choices underpinning the inherent nature of such a design. Do hierarchical systems have some sort of inherent properties that make them more advantageous to land-use classification? Do other reasons exist to prefer such approaches, such as technical limitations or perhaps being more amenable to publication and potential use?

Based on a review of the literature, we identified and report on a series of four types of classification systems that lie along a continuum from basic and simple to more sophisticated and complex: categorical, hierarchical, multidimensional, and semantic. The first two are used commonly in reporting, for example, map legends, while the latter two are used for more specialized purposes, for example, comparisons of different classifications.

### Categorical

A categorical classification generalises and organises land-use information to create discrete classes, categories or units (figure 1). Each class or unit is identified by an alphanumeric code of some type, and the code is linked to a written description. The structure of the classification includes no information on relationships or associations among classes. Furthermore, descriptive information is usually not available for further querying or processing.

Categorical classifications employ spatially discrete (non-overlapping) mapping units. For this reason they are very useful for cartographic applications and reports such as the map of land cover contained in the recent New Zealand State of the Environment report (Ministry for the Environment 2007, p230). Categorical classifications can only accommodate a finite number of classes before becoming unwieldy either conceptually or cartographically.

![Figure 1: Categorical land-use classification](image)

### Hierarchical

Nearly all the systems reviewed were hierarchical in structure (Duhamel 1998; Műcher et al 1993; Scace 1981). Each was developed for a specific geographic area, presumably by researchers with considerable expertise in the area for which they were devised.

Hierarchical systems add structure to a categorical classification by identifying relationships or links among different units. The different classes are organized into a series of theoretically discrete levels where a class at a higher level is partitioned into two more classes at the next lower level (figure 2). An attempt is usually made to insure classes at the same level reflect a similar level of descriptive detail, although that objective is not always easily met. The coding system is also almost always hierarchical, such that the number of alphanumeric digits indicates the number of classification levels and relationships among classes, (eg, 100 = urban, 110 = urban residential, 113 = urban residential high-rise apartment). The New Zealand Land Cover Database Version 2 is an example of a 2-level hierarchical classification (Thompson et al 2003).
In hierarchical classifications information is gained going from higher to lower levels, for example, from agriculture to animal or plant, as in figure 2. Information is lost going from lower to higher levels. Other than group membership, hierarchical classifications store no additional information on relationships among classes. Additional information about the classes themselves or further inferences about relationships among classes must be determined from associated descriptive information.

Classes can be aggregated or disaggregated as required for different purposes, such as showing more or less detail on a map. In spatial applications such as land use, the area of the related classes at a lower level almost always sums to equal the total area of the related class at the next higher level. From a cartographic perspective, hierarchical classifications have the advantage of being able to be mapped at different information resolutions or levels, thus enabling classifications with many categories to be mapped more easily.

**Figure 2**
Hierarchical land-use classification

Categorical and hierarchical classifications are relatively information poor. Generalizing the world into predetermined classes with no or limited relationship information requires a trade-off between specificity and classification size. Multidimensional classifications partially overcome those limitations by including information about multiple attributes, each of which represents a separate dimension in a multidimensional information space (e.g., Arozarena et al 2006; Jeer 1997). Each dimension can contain different types of information, for example, categorical, ranked, or continuous, and could represent a categorical classification in its own right. When represented spatially, a multidimensional classification facilitates different combinations of the underlying attribute information, such that each attribute could be depicted individually or in combinations with other attributes (figure 3).
Mathematically the maximum number of possible classes $N_{\text{max}}$ is determined by the dimensionality of the classification as follows:

$$N_{\text{max}} = n_1 \times n_2 \times \ldots \times n_d$$

where $n$ is the number of unique values along dimension $d$. Therefore, a 2-dimensional classification with 10 classes per dimension would have a theoretical maximum of 100 classes. Adding additional dimensions of information has the potential to significantly increase the possible number of classes. In reality, some attribute combinations would be extremely unlikely (eg, dairying on a motorway), such that the actual number of possible classes are much lower.

Similar to hierarchical classifications, multidimensional classifications allow for different levels of classification detail. Unlike hierarchical classifications, however, multidimensional classifications are not limited to a single predefined set of relationships. Attribute information can be recombined in different ways to produce different classifications to suit a range of different purposes, including producing a hierarchical classification if desired. Also, whereas placement of an element within a hierarchical classification can sometimes be ambiguous (Sneath & Sokal 1973, p382), multidimensional classifications can overcome those problems by retaining a more complete set of information about each element. Conversely, such classifications require information for each dimension or attribute. In many cases such information may not be available or may not be appropriate.

Land Environments of New Zealand (LENZ) provides one example of a multidimensional classification (Leathwick et al 2003a, 2003b). LENZ is a multidimensional classification based on a set of 15 attributes of climate, landform, and soil that influence biotic pattern within New Zealand. While operationalised as a hierarchical classification consisting of 4 levels and up to 500 classes or land environments, the underlying classification consisted of over 750 classes categorised non-hierarchically.

The increased amount of information embedded within multidimensional classifications reduces the ease with which all unique entities can be mapped, although different techniques can be applied to help overcome those limitations (Leathwick et al 2003b). However, the potential simplification of data within each dimension can improve overall cartographic flexibility as each dimension can be treated as an independent cartographic entity.
Semantic
Recent advances in computing technology, especially processing speeds and storage capacity, have generated opportunities to develop new approaches in land-use classification. Semantic classifications link information (attributes) and structure (classification) within a single database (Mayall 2002). Removing the necessity to predefine either the structure or the classification units permits the storage of vastly greater amounts of information within the system as it is developed and implemented. Semantic classifications can also store metadata, ie, ‘data about data,’ directly. This removes the need to create a separate metadata file and insures that metadata are always available.

Semantic classifications derive from linguistic theory (Mayall & Hall 2005). They consist of a ‘vocabulary’ of object types, for example, polygons, and a ‘syntax’ consisting of a set of (spatial) rules defining the relationships among the object types. Together, the object types and spatial rules define a ‘grammar.’ Object types typically represent real-world objects such as buildings, trees, etc, with relationships among objects usually arranged hierarchically from more abstract to more specific, for example, tree–podocarp–rimu. Similar to a multidimensional classification, users construct different queries or, following the linguistic theme, different ‘sentences’ to produce different classifications, interpretations or visualisations of the landscape (figure 4).

Such a system has been used to embed landscape information (Mayall 2002). With regard to land-use classifications, semantic methods have thus far only been used to compare pre-existing land-use classifications (Feng & Flewelling 2004).

The increased complexity of a semantic classification is not without cost. Defining the classification dataset and querying it would incur much higher costs both in terms of human capability and computational overheads. From an analytical and cartographic perspective, it is probably better to consider a semantic classification as the starting point for or foundation of derived products, for example, a hierarchical classification. These derived products would contain a predefined subset of the information contained in the semantic classification based on a simpler data model.

**Figure 4**
Semantic land-use classification

Note: A–E represent classification units/object types, each with a corresponding description of land use. Q1 and Q2 represent different queries based on predefined syntax rules that produce different interpretations or classifications to suit different needs.
Comparative review of land-use classifications

In this section we summarise the literature on comparative analyses of land-use classifications. A large number of proposed classifications have been developed and published (Duhamel 1998; Jeer 1997; Lesslie 2004; Mücher et al 1993; Young 1994). We have drawn our summary from the considerable critique of existing classifications within the body of these papers.

Guttenberg (1993, p29) argued that land use is too broad a concept to be adequately described or defined in a single dimension. The act of identifying more than one dimension was seen as revolutionary when it was first proposed. In the United States at least, this idea has taken considerable hold. Guttenberg identified eight potentially independent dimensions that might be considered when developing a land-use classification:

- Observable Characteristics
- General Site Development
- Special Site Development
- Actual Use (Activity Type)
- Activity Characteristics
- Underlying Characteristics
- Economic Over-Use (Underlying Function)
- Legal Relationships (ownership, etc).

Young (1994) identified two broad elements of land use. Young’s elements did not coincide entirely with Guttenberg’s dimensions but acknowledged that the information contained within each might be usefully independent:

Functional land use: The purpose for which the land is used, or the benefits obtained from it; benefits may be products (eg, crops, wood) or services (non-material benefits, eg, conservation, recreation).

Biophysical land use: The sequence of operations carried out on an area of land to obtain products or other benefits; examples are vegetation clearance, ploughing, grazing, building, and the application of material inputs, for example, fertilizers.

Lesslie (2004, p2) summarized the general condition of land-use classification as follows:

Classification systems are generally either hierarchical or non-hierarchical. Most systems are hierarchically structured because this accommodates different levels of information starting with structured broad-level classes allowing further subdivision into more detailed sub-classes. At each level defined classes are mutually exclusive.

An a priori classification is based upon the definition of classes before data collection takes place. This means all possible combinations of diagnostic criteria must be resolved beforehand by the classification. The main advantage is that classes are standardized, independent of the area under investigation and methods employed. However, some identified objects may not be easily assigned to pre-defined classes.

A posteriori classification is based upon definition of classes after clustering, based on the similarity or dissimilarity of field samples. The advantage of this type of classification is flexibility, adaptability and minimal generalization. However, because this approach depends on the specific characteristics of area under investigation, it is unable to define standardised classes.

The essential problem is that a single classification cannot suit every use in every place. Malingreau and Christiani (1981) recognised the realistic limitations of land-use classifications as follows:

“In devising a land-use classification, it is obviously not possible to retain all of its characteristic features; classification criteria have to be selected and this implies some features will be emphasised and some others neglected.” Malingreau (1977) nicely summed up the problem when he wrote:

“There is no ideal classification of land cover/land use which will satisfy the needs of all surveyors. Each of them has indeed particular features of interest which he will observe in more details than..."
others... It is in this context that the need arises for a classification framework which encompasses most of the land-use features having some significance for the evaluation of the areas under consideration."

Given the challenges and limitations in developing and applying land-use classifications, it is therefore not surprising that a typical outcome, after reviewing previous land-use classifications systems, is to propose a new classification (Duhamel 1998; Jeer 1997; Mücher et al 1993; Young 1994; and Di Gregorio & Jansen (1998) for a similar approach to land cover). Each of those studies reviewed previous land-use classifications and, finding them lacking, proposed a new classification based on various considerations or criteria. Hierarchical classifications appear to be the most common. Duhamel (1998), for example, proposed an eliminatory method to land-use classification based on a functional approach. In his system, land use would be classified into various socioeconomic activities using four key classifiers applied sequentially: process, tangible produce, primary product, biological product. This would in turn be linked to internationally recognised socioeconomic classifications such as the International Standard Classification of all Economic Activities.

Some, however, have proposed alternative multidimensional systems. The American Planning Association (APA) has a land-based classification system (reviewed later in this report) that classifies land – not just land use – along 5 dimensions: activity, structure, function, site development character, and ownership (http://www.planning.org/lbcs/). Each dimension has its own categories and subcategories. The APA system promotes flexibility in land-use classification and states that different dimensions would be included or excluded as needed. The APA website includes a range of tools including various database models for use in applying the classifications system.

Interestingly, in New Zealand, Cumberland (1944) proposed a land-classification system (discussed later in more detail) adopted from a US-based system that included much of the same information as in the APA system proposed nearly 50 years later. Although not specifically targeted at land use, the New Zealand Land Resource Inventory (Newsome 1992) included many aspects of Cumberland’s system.

Adoption and Specification

Of the many systems reviewed, very few appear to have been implemented as a spatial dataset. Why did these systems fail to be adopted? It might be argued that it is easier to find money to design a project than to implement it. However, justifications for developing each classification are often presented in the introduction to each new system, where rejection of previous examples is justified. According to Mücher et al (2003), classification systems fail for one or more of the following reasons:

- The lack of a sound definition of the units of analysis: these may range from field to farm to region and are too often confused with the mapping unit.
- Overlapping land-use classes because of poorly defined criteria. Most hierarchical classifications are only comprehensive for their scope of interest at the first hierarchical level, but are far from comprehensive at lower hierarchical levels.
- Subjective assignment of land use to a specific class due to the nearly ubiquitous absence of quantitative class boundaries, for example, critical or threshold values of included criteria.
- The combination of land use with other features such as climate characteristics that may influence land use but are not inherent features of land use.
- Objectives of land-use classification are often closely tied to regional or disciplinary focus.

Having critiqued existing classifications, Mücher et al (1993) identified the following as being the features of a sound and universally applicable land-use classification:

- Comprehensive.
- **Criteria must be based on inherent characteristics only of land use.** Land-use classification will have as its only object land use. In this way the land-use classification will be complementary.
to other classifications, for example, soil classification, vegetation classification and farming-systems classification, yet all of these should be independent.

- **Determining factors** or diagnostic criteria for the classification of land use should be as stable as possible, meaning they are characteristic for the land use over a longer time period (e.g., burning is one of the determining characteristics of shifting cultivation, although the action takes place in a few hours or in a few days).

- The **basic unit of analysis**, as the unit of observation, will be the ‘unit of biophysical management’. For forestry, livestock production systems, and fishery the terms field, parcel, or plot are not useful. The term ‘unit of biophysical management’ is the only useful term for the basic unit of analysis, because it is the only term that can be applied to all land use. Still, the ‘unit of biophysical management’ for arable cropping is the plot.

- The **diagnostic criteria**, independent of the hierarchical level in the classification, will be differentiating characteristics at the ‘field’ level. This approach is similar to the use of diagnostic horizons in soil classification. However, some biophysical characteristics of the land use, like infrastructure and irrigation, are not implemented at the plot level, but are implemented at a higher level. As an exception, infrastructure and irrigation will be expressed as characteristics of each of the ‘units of biophysical management’ for which they are relevant.

- Contrary to the basic unit of analysis (e.g., plot), which is scale dependent, the land-use classification as such will be scale independent; meaning the classes of the highest hierarchical level in the land-use classification, and the classes of lower hierarchical levels should be applicable at any scale or level of detail.

- The land-use classification is a **multicategorical** system, with only a few diagnostic criteria at the highest level of the hierarchy and a restricted number of classes. With a decreasing level in the hierarchy the number of diagnostic criteria increases together with the number of classes. Diagnostic criteria at one level of the hierarchy of the land-use classification should not be used again at a lower level of the hierarchy as diagnostic criteria.

- The approach for a land-use classification should be as pragmatic as possible within limits set by the concept. The main users of the land-use classification will be policy makers of international organizations, policy makers in national organizations, land-use planners, and scientists. They will be working on a global/continental scale, at a national scale or at a regional scale. The hierarchical levels of the land-use classification should be convenient for the user, and should be applied easily by any of the above mentioned groups.

- The land-use classification should have a logical and scientifically sound foundation. The Soil Taxonomy and FAO soil classification are strongly related to the general principles of soil genesis, ie, based on ‘pedogenetic’ principles. The sets of quantitatively defined properties, produced by soil forming processes, have made it possible to base the guiding principles of classification on the principles of soil genesis. Similarly, biological taxonomies are ‘phylogenetic’, ie, based on the evolution of species. To reflect fully the dynamics of land use, land-use classifications should be related to the evolution of land use, ie, ‘usugenetic’.

In the USA, Anderson et al (1976) developed a land-use and land-cover classification system derived from remote sensing. Their system identified 10 essential criteria for a land-use classification, which both agreed and contrasted with those of Mücher et al (1973):

- The minimum level of interpretation accuracy in the identification of land-use and land-cover categories from remote sensor data should be at least 85 percent.

- The accuracy of interpretation for the several categories should be about equal.

- Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.

- The classification system should be applicable over extensive areas.

- The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.
The classification system should be suitable for use with remote sensor data obtained at different times of the year.

Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.

Aggregation of categories must be possible.

Comparison with future land-use data should be possible.

Multiple uses of land should be recognized when possible.

Scace (1981) prepared a reasonably comprehensive overview of land-use classification systems but with some critique on the relative merits of each classification. That document cites Clawson (1965, unread) as recognizing the following major ideas or concepts about land use. Scace identified 9 attributes, modified here for simplicity:

- Location – of unit area (parcel)
- Activity – purpose of use
- Characteristics – physical surface, subsurface, vegetation, etc
- Modifications – ‘improvements to and on land’
- Intensity – amount per unit area
- Tenure – who: of ownership, use, etc
- Value – fiscal value of the land
- Interrelation between activities
- Interrelations between parcels.

Few, if any, of the systems reviewed by Scace appear to possess more than one or two of these attributes, and none of the more than 40 classifications were documented as being anything other than categorical or hierarchical.

However, Mayall and Hall (2005), and Feng and Flewelling (2004) have demonstrated that other approaches to the classification of land are both technically possible and almost certainly feasible in the context of the current problem.

For those wishing to compartmentalise the real world into a classification there is a natural tendency to develop something that is immediately transparent and obvious. However, in doing so it is quite possible the subtle nuances so important from an analytical perspective are lost. For example, Guttenberg (1992, p51–57) wrote:

“Classifications are supposed to be useful, but they also have another function, which is to reveal and clarify the nature of the subject or object classified, and it is in this sense that so many contemporary land-use classifications fail.”

Guttenberg (1993) asserted that a classification must be poetic in the deepest sense of the meaning. The process of classification should respect the richness and variety of land use, the subject. Indeed, the classification system ought to present a grammar that can help represent the many facets of land use – in this essay referred to as fields (modified):

- Referential
- Nominative (names the use)
- Locative (locates the use)
- Substantive (identifies the use type)
• Possessive (identifies legal characteristics)
• Appraisive
• Qualitative (evaluates the use)
• Quantitative (quantifies the use).

The grammar described by Guttenberg was a very primitive one from a computational perspective and easily implemented using a multidimensional framework. However, as described earlier, Mayall and Hall (2005) have demonstrated it is possible to describe the landscape using more complex semantic concepts and tools. Their work was specifically designed for the spatial representation of a described landscape using three-dimensional modeling tools.

Lessons learned
The contrasting views and opinions presented in the previous section highlight the challenges and difficulties in developing, implementing, and maintaining a robust and enduring land-use classification. Taken in aggregate the key issues identified include:

• Classification purpose
• Classification scope, eg, what elements or attributes to include or not include
• A priori or a posteriori (eg, Lesslie 2004)
• Tension between continuity and stability versus flexibility and adaptability
• Units of analysis including, for the purpose of this report, geospatial units of analysis
• Relationship and/or confusion with other land attributes, eg, cover, tenure
• Temporal considerations, ie, the sequence of activities undertaken over time that help define land use (Young 1994)
• Inevitable loss of knowledge and information.

The characteristic they share is the focus on a single classification, whether it is categorical, hierarchical, or multidimensional. The semantic approach overcomes those issues by focusing classification effort on the concepts and ideas of land use, in the sense outlined by Guttenberg (1993), to develop a shared vocabulary and language of land use. Provided those rules and guidelines are followed, scope can expand and contract to fit the purpose, stability and flexibility are served simultaneously, analysis units can vary both conceptually and spatially, relationships among land uses and to other land attributes can be explicitly defined, temporal activities can be easily embedded, and information and knowledge can be retained and built-up over time.
3 International land-use classification

Global

Globally there are many proposed land-use classifications including those of Adamec (1992), Chapin and Kaiser (1979), Duhamel (1998), ECE-UN (1989), Mücher et al (1993), and Young (1994). In addition to proposing a reference land-classification system, Duhamel (1998) provides a good review. Further information about these systems and a number of others can be found on the FAO Land & Water Development Division land-use website (http://www.fao.org/ag/agl/agll/landuse/).

All the proposed systems are hierarchical, ranging from a single level – which essentially renders them as categorical (Adamec 1992) – to eight levels (Duhamel 1998). As discussed previously, the manner of the classification depends on the concept and criteria used. The Chapin and Kaiser (1979) system, for example, has three levels. The first is defined along a gradient of modification from natural ecosystems to settlements. The second level divides uses by function, and the third level divides uses by biophysical land use. Duhamel’s (1998) hierarchical classification derives from an activity-based flow diagram that provides branching points based on the following series of questions:

- Process vs no process (eg, conservation)
- Tangible (eg, goods) vs intangible (eg, services, residential)
- Primary (eg, earth-based) vs Secondary or Derived (eg, manufacturing)
- Biological (eg, agriculture, fishing) vs Mineral (eg, mining)
- Duhamel’s classification provides finer and finer detail, and at the lowest (eighth) levels offers insights into the temporal sequence of activities undertaken for some agricultural land uses, for example, ‘Class 1.1.1.1.0.1.1 - crops from shifting cultivation’.

Despite continued attempts at developing a global land-use classification, we found no evidence of an accepted standard land-use classification. In addition, a review by George and Nachtergaele (2003) documented a relatively paucity in global land-use information. They found that land-use information often forms elements or small parts of datasets devoted to other themes, for example, land-cover mapping from satellite imagery.

George and Nachtergaele (2003) also found high variability in the availability and quality of land-use information produced on a country basis. Reasons for variation in land-use information quality include: information is not kept up to date; coverage is incomplete; varying definitions of land-use categories even within countries; or the methods used for inventoring land use are unsuitable. They note that these deficiencies pose barriers to compiling consistent, accurate regional to global information on land use and land-use change. However, George and Nachtergaele also noted that decreasing costs of satellite imagery could help overcome some of those barriers and foster the development of consistent national, regional, and global land-use information and classification.

Finally, Young (1994) identified the following issues for revision of existing land-use classification systems:

- Lack of complete inventories of existing land uses
- Lack of definitions of land uses, land-use activities and functions
- Lack of consistency in categorizing land uses in a manner consistent with legislation
- Broader user expectations
- Lack of standards for data collection
- Insufficient accounting of certain activities
- Lack of reliability of land-use data
- Lack of standards for sharing land-use information.
Selected countries

Below we provide overviews of four selected countries with relatively advanced land-use classification systems: Australia, Spain, United Kingdom, and the United States. These examples serve to illustrate how other countries are proceeding with the development, implementation, and maintenance of land-use classification. Australia and the United Kingdom have hierarchical classification systems, the United States has a multidimensional classification system, and Spain is developing a system that falls somewhere between a multidimensional and semantic classification system (although leaning more towards the multidimensional).

Australia

The Australian Collaborative Land Use Mapping Programme (ACLUMP) is a consortium of national, state, and territorial government partners that promotes the development of nationally consistent land-use and land-management practice information for Australia, which includes the development of a land-use classification.

In February 1999, a joint workshop involving Australian national, state and territory authorities adopted a modified version of a classification scheme developed by Baxter and Russell (1994). This scheme would promote the creation of nationally consistent, although not necessarily uniform, land-use dataset and classification to meet a wide range of user needs, and make the best use of existing data and available resources. This classification scheme, the Australian Land Use and Management (ALUM) Classification, has been the subject of an on-going consultative review process and was at Version 6 as of June 2005.

The ALUM classification has a three-tiered hierarchical structure with primary, secondary and tertiary classes broadly structured in terms of the potential degree of modification and impact on a putative ‘natural state’ (essentially unmodified native land cover), (figure 5). Primary and secondary classes relate to land use – the prime use of the land defined in terms of the management objectives of the land manager. Tertiary classes can include commodity groups, commodities, land-management practice, or land-cover (eg, vegetation) information. Tertiary agriculture classes have been based on Australian Bureau of Statistics commodity groups as well as on dominant land management practices.

The primary classes are:

- **Conservation and Natural Environments** – used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems already present.
- **Production from Relatively Natural Environments** – used mainly for primary production, based on limited change to the native vegetation.
- **Dryland Agriculture and Plantations** – used mainly for primary production, based on dryland farming systems.
- **Irrigated Agriculture and Plantations** – used mainly for primary production, based on irrigated farming.
- **Intensive Uses** – subject to substantial modification, generally in association with closer residential settlement, commercial, or industrial uses.
- **Water** – water features are regarded as essential to the classification system although they are primarily land-cover types.

The classification is intended to be flexible such that new land uses or management systems can be accommodated as long as there is no conflict with other existing items.
The principles that underpin the ALUM Classification approach include:

1. **Levels of intervention** – The classification is based on identification and delineation of types and levels of intervention in the landscape, rather than descriptions of land use based on outputs. It also gives precedence to the modelling capabilities of data over monitoring capabilities, and monitoring capabilities over descriptive uses.

2. **Generality** – The classification is designed to cater for users who are interested both in processes (eg, land management practices) and in outputs (eg, commodities).

3. **Hierarchial structure** – A hierarchial structure provides for and promotes aggregation/disaggregation of related land uses, the addition of levels or classes, and relevance at a range of scales.

4. **Prime use/ancillary use** – Parcels of land may be subject to a number of concurrent land uses. A multiple-use production forest, for example, has as its main management objective the production of timber, although it also may provide conservation, recreation, grazing and water catchment services. Land-use class allocations based on prime use are based on the primary land management objective of the nominated land manager. Ancillary or secondary uses can also be recorded.

In addition to the ALUM Classification, other land-use classifications in use in Australia are the Western Australian Standard Land Use Classification (WASLUC) and the Australian and New Zealand Land Use Classification (ANZLUC). Both are hierarchical with nine primary classes of land use.

**Spain**

SIOSE (Sistema de Información de Ocupación del Suelo en España) is an integrated land-use/land-cover information system under development by the Spanish National Geographic Institute (Arozarena et al 2006). SIOSE is intended to facilitate sharing of information within Spain and between Spain and the broader European Union and has 6 specific objectives:

1. Avoid duplicity and reduce geographic information costs
2. Share production and quality control among national and regional administrations

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**Note:** Available at: http://adl.brs.gov.au/mapserv/landuse/index.cfm?fa=
3. Satisfy future land-cover information requirements of the European Environment Agency
4. Satisfy requirements of Spanish national and regional administrations
5. Satisfy requirements of the Spanish National Geographic Institute
6. Integrate land cover and use databases across all Spanish national institutions.

The SIOSE project aims to develop a normalised data model and harmonise information across a range of Spanish institutions. The approach is to develop an object-oriented data model that can overcome the various limitations inherent in a hierarchical classification. In the proposed data model, polygons can have one or more covers and one or more thematic attributes. For example, polygons mapped at the finest resolution possible (i.e., the minimum mapping unit) but still containing more than one cover type will have an associated set of information listing the percent of all included cover types. Similarly, a polygon could have several associated attributes describing different socioeconomic aspects of land use. The data model can be extended over time as new information becomes available.

The SIOSE model represents an intermediate approach between a multi-dimensional classification and a true semantic database. Like a multidimensional classification, it can include multiple criteria or attributes, each having multiple values. Like a semantic classification, the data model appears to be more fluid such that classification units only contain the relevant or available information. However, unlike a true semantic database, it does not appear that the SIOSE classification will completely utilise the grammar and syntax concepts.

The technical features of SIOSE include a nominal scale of 1:25 000, a minimum mapping unit of 1-2 hectares, and plans for it to be updated at least every four years. Currently, SIOSE is still in production and thus far remains predominantly a land-cover database.

United Kingdom

The National Land Use Database (NLUD) was developed as a framework for land-use classification, with the latest version known as NLUD version 4.4. The NLUD is a hierarchical classification with 13 order names and 41 group names. The classification builds on previous land-use classifications by addressing their shortcomings and considers current policy priorities (www.nlud.org.uk).

The specific aims of the classification are to establish a national system for naming and defining groups of land use and land-cover features, to provide a nationally consistent basis for identifying, recording and reporting land use and land cover, and to be used as a standard classification involved in routine collection of land use and land-cover data (Harrison 2006).

Data sources identified for deriving the NLUD classification included:

- Feature codes and text association from Ordnance Survey digital mapping
- Communities and local government land-use change statistics
- Aerial photography
- Satellite data
- Address-based data.

It should be noted that at present there are no plans to implement the full NLUD. However, a simplified version, the Generalised Land Use Database (GLUD), has been created. It employs some of the methodology developed for the full NLUD but has only nine land-use categories that are actually mainly land cover, except that residential buildings are shown separately from other buildings.
### Table 2
Orders and groups within the UK National Land Use Database

<table>
<thead>
<tr>
<th>Code</th>
<th>Orders</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Agricultural</td>
<td>1.1 Agriculture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 Fisheries</td>
</tr>
<tr>
<td>2.0</td>
<td>Forestry</td>
<td>2.1 Managed forest</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2 Un-managed forest</td>
</tr>
<tr>
<td>3.0</td>
<td>Minerals</td>
<td>3.1 Mineral workings and quarries</td>
</tr>
<tr>
<td>4.0</td>
<td>Recreation and Leisure</td>
<td>4.1 Outdoor amenity and open spaces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.2 Amusement and show places</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.3 Libraries, museums and galleries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.4 Sports facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5 Holiday camps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.6 Allotments and urban farms</td>
</tr>
<tr>
<td>5.0</td>
<td>Transport</td>
<td>5.1 Transport tracks and ways</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.2 Transport terminals and interchanges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.3 Car parks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.4 Other vehicle storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5 Goods and freight handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.6 Waterways</td>
</tr>
<tr>
<td>6.0</td>
<td>Utilities and Infrastructure</td>
<td>6.1 Energy production and distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.2 Water storage and treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.3 Refuse disposal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.4 Cemeteries and crematoria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.5 Post and telecommunications</td>
</tr>
<tr>
<td>7.0</td>
<td>Residential</td>
<td>7.1 Dwellings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.2 Hotels, boarding and guest houses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.3 Residential institutions</td>
</tr>
<tr>
<td>8.0</td>
<td>Community Services</td>
<td>8.1 Medical and health care services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.2 Places of worship</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.3 Education</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.4 Community services</td>
</tr>
<tr>
<td>9.0</td>
<td>Retail</td>
<td>9.1 Shops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.2 Financial and professional services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.3 Restaurants and cafes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.4 Public houses, bars and nightclubs</td>
</tr>
<tr>
<td>10.0</td>
<td>Industry and Business</td>
<td>10.1 Manufacturing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.2 Offices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.3 Storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.4 Wholesale distribution</td>
</tr>
<tr>
<td>11.0</td>
<td>Previously Developed Land</td>
<td>11.1 Vacant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.2 Derelict</td>
</tr>
<tr>
<td>12.0</td>
<td>Defence</td>
<td>12.1 Defence</td>
</tr>
<tr>
<td>13.0</td>
<td>Unused Land</td>
<td>13.1 Unused Land</td>
</tr>
</tbody>
</table>
United States

In the United States land-use classification has been strongly influenced by 1) the Standard Land Use Coding Manual (SLUCM) published in 1965 by the Urban Renewal Administration and Bureau of Public Roads (Urban Renewal Administration, Housing and Home Finance Agency, and Bureau of Public Roads, Department of Commerce, 1965), and 2) a combined land-use/land-cover classification developed in 1976 by Andersen et al (1976).

SLUCM focused primarily on urban areas and created a detailed, hierarchical four-level system based largely on the US Standard Industrial Classification as it existed at the time. The manual was intended to foster consistency of land-use information collection and classification across a range of federal, state, and local agencies. Before the preparation of the manual, collection of land-use information within the United States was often ad hoc such that "...land-use data collected for one specific purpose had little or no value for another but similar purpose..." (p1). Land-use information collected under the new system was intended to improve the value of the collected information for a variety of purposes including research, statistical analysis, and tracking of land-use trends over time.

In preparing SLUCM, over 50 existing classification systems were reviewed and numerous land-use specialists were consulted. A major conclusion of this review was that different aspects of land use should not be combined in a single classification. Instead, each separate dimension of land use should have its own corresponding classification system. The characteristics were considered 'building blocks' that could be reassembled in various manners to suit different purposes.

Of the broad variety of possible land-use attributes identified, the manual focused on classifying activities because activities was the single most important attribute for which comparability was desired. With regard to activities, the review reached a second major conclusion that no 'rigid' system for classifying land use across the United States was feasible. Instead the report recommended developing a detailed land-use classification that allowed for consistency of coding but permitted flexibility of use once land-use codes were determined. The manual states that provided land use is coded at the finest level of detail (ie, a four-digit code), the land-use information could be recombined as needed to suit a variety of purposes. The manual then proceeded to outline the full classification, starting with the first level of nine classes (table 3) that, in a somewhat contradictory fashion, included manufacturing twice.

Anderson et al (1976) developed a similar albeit less detailed land-classification system to complement the SLUCM because, as the authors noted, only 5 percent of the US land area contained urban uses that were the focus of the SLUCM manual. Additional classification was needed for the remaining 95 percent of the USA having a natural resource focus. The Anderson system was developed primarily for the emerging suite of remote sensing technologies under development at the time. It included a mixture of land use and land cover at two levels (table 4).
Table 3
First level codes and classes from the US Standard Land Use Coding Manual (1965)

<table>
<thead>
<tr>
<th>Code</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential</td>
</tr>
<tr>
<td>2</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>3</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>4</td>
<td>Transportation, Communication &amp; Utilities</td>
</tr>
<tr>
<td>5</td>
<td>Trade</td>
</tr>
<tr>
<td>6</td>
<td>Services</td>
</tr>
<tr>
<td>7</td>
<td>Cultural, entertainment, &amp; recreational</td>
</tr>
<tr>
<td>8</td>
<td>Resource production &amp; extraction</td>
</tr>
<tr>
<td>9</td>
<td>Undeveloped land &amp; water areas</td>
</tr>
</tbody>
</table>

As discussed earlier, many studies have highlighted the limitations of hierarchical approaches to land-use classification. To overcome those limitations, the American Planning Association developed the Land-Based Classification Standards (LBCS) project (Jeer 1997). The project identified a number of key issues with existing classification systems. For example, despite SLUCM’s 80+ pages of land-use codes, including footnotes and in some cases 3D drawings to guide classification of different uses within a building, the LBCS project identified such issues as a “lack of a list of definitions of land uses and land-use activities and functions” or “classification standards that cannot recognize the sources of land-based data other than parcel-based sources.”

In particular, the project recognised an urgent need for a full inventory of land-based resources and recognised explicitly the need to consider and classify all aspects of land-based resources, including use, activity, cover, and rights (ie, tenure or ownership) (Jeer 1997). The project concluded that a land-based classification should a) contain categories about land-based information, b) include enough categories to discriminate various land-based characteristics, and c) identify relationships among categories. The report went on to discuss the various criteria for selecting categories, examined categories used in other systems, and discussed principles for defining relationships including evaluating the benefits and drawbacks of different systems, for example, categorical, hierarchical, and multi-dimensional.

The final result of this project was the development of the LBCS. To repeat briefly, the LBCS is a land-based classification system that classifies land along five dimensions: activity, structure, function, site development character, and ownership (www.planning.org/lbcs), each with its own categories and subcategories. The LBCS system includes a range of tools including various database models for direct application.
## Table 4
Land-use/land-cover codes and categories from the Anderson et al system

<table>
<thead>
<tr>
<th>Code</th>
<th>Level I</th>
<th>Level II</th>
</tr>
</thead>
</table>
| 1    | Urban or Built-Up Land         | 11 Residential
|      |                                | 12 Commercial and Services
|      |                                | 13 Industrial
|      |                                | 14 Transportation, Communications, and Utilities
|      |                                | 15 Industrial and Commercial Complexes
|      |                                | 16 Mixed Urban or Built-up Land
|      |                                | 17 Other Urban or Built-up Land |
| 2    | Agriculture                    | 21 Cropland and Pasture
|      |                                | 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
|      |                                | 23 Confined Feeding Operations
|      |                                | 24 Other Agricultural Land |
| 3    | Rangeland                      | 31 Herbaceous Rangeland
|      |                                | 32 Shrub and Brush Rangeland
|      |                                | 33 Mixed Rangeland |
| 4    | Forest Lands                   | 41 Deciduous Forest Land
|      |                                | 42 Evergreen Forest Land
|      |                                | 43 Mixed Forest Land |
| 5    | Water                          | 51 Streams and Canals
|      |                                | 52 Lakes
|      |                                | 53 Reservoirs
|      |                                | 54 Bays and Estuaries |
| 6    | Wetlands                       | 61 Forested Wetland
|      |                                | 62 Non-forested Wetland |
| 7    | Barren Lands                   | 71 Dry Salt Flats
|      |                                | 72 Beaches
|      |                                | 73 Sandy Areas other than Beaches
|      |                                | 74 Bare Exposed Rock
|      |                                | 75 Strip Mines Quarries, and Gravel Pits
|      |                                | 76 Transitional Areas
|      |                                | 77 Mixed Barren Land |
| 8.0  | Tundra                         | 81 Shrub and Brush Tundra
|      |                                | 82 Herbaceous Tundra
|      |                                | 83 Bare Ground Tundra
|      |                                | 84 Wet Tundra
|      |                                | 85 Mixed Tundra |
| 9.0  | Perennial Snow and Ice         | 91 Perennial Snowfields
|      |                                | 92 Glaciers |
4 Review of Land-use classification in New Zealand

Over the past 60 years there have been three attempts to develop an official land-use classification for New Zealand. A recent unofficial national land-use classification was compiled for the CLUES project (Woods et al 2006). Land Information New Zealand (LINZ) also includes a basic land-use classification system in the rating valuation rules prepared under the Ratings Valuation Act (LINZ 2008). Below we briefly review and discuss those different land-use classification systems.

Survey and classification for land in New Zealand: a basis for planning (1944)

Cumberland (1944) proposed one of the earliest land-use classification systems for New Zealand. Cumberland was concerned about the long-term viability of food production from New Zealand’s soils and developed the classification to support rapid survey of New Zealand’s land resources following the Second World War. The survey would attempt to identify ‘unit areas’ of the landscape no less than 200 hectares in extent and to characterise them using fractional notation to identify “all factors relevant to planning” (Cumberland, 1994, p187).

Cumberland advocated adopting a system developed by the Tennessee Valley Authority, an organisation in the United States similar to former catchment boards, for classifying land use. Cumberland’s system for New Zealand categorised attributes into five broad groups and developed a fractional notation scheme that organised those categories (figure 6). Each individual category was then represented by a set of numbers, letters, or roman numerals yielding the following notation as follows:

Figure 6
Fractional notation proposed by Cumberland for land classification

For each group Cumberland provided a corresponding table that contained the complete set of possible numerical or alphabetic codes for each digit in the fractional notation and a corresponding description. As an example, Table 5 reproduces Cumberland’s table for the ‘Use of the Land’ codes represented by the 7-digit numerator of the leftmost fraction. The final land classification represented by the Roman numeral provided an overall classification based on a synthesis of “the Economic Status of its People, its Inherent Agricultural Qualities, and its Physical Conditions” (Cumberland 1944, p191).

Conceptually, the system represented an early attempt at defining a multidimensional land-use classification system that, even by today’s standards, was extremely comprehensive. As mentioned earlier, the New Zealand Land Resources Inventory (Newsome 1992) incorporates many concepts and aspects of Cumberland’s system.
Table 5
Possible attribute values for the seven digits represented in the numerator of the left-hand fraction of the Cumberland notation

<table>
<thead>
<tr>
<th>First Digit</th>
<th>Second Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contemporary Land use</td>
<td>Farm and Station Crops, Stock and Economy</td>
</tr>
<tr>
<td>Agricultural</td>
<td>Cereals</td>
</tr>
<tr>
<td>Pasture (rotation)</td>
<td>Root/Pulse/Green Fodder</td>
</tr>
<tr>
<td>Pasture (permanent)</td>
<td>Grass &amp; Clover for Seed</td>
</tr>
<tr>
<td>Native Grassland (mainly tussock)</td>
<td>Orchards</td>
</tr>
<tr>
<td>Scrub, Fern, &amp; Exotic Weeds</td>
<td>Market Gardening &amp; Nurseries</td>
</tr>
<tr>
<td>Forest (native &amp; exotic)</td>
<td>Other Intensive Crops</td>
</tr>
<tr>
<td>Unused – suitable for other uses</td>
<td>Store Sheep</td>
</tr>
<tr>
<td>Unused – unsuitable for other uses</td>
<td>Sheep Breeding and Rearing</td>
</tr>
<tr>
<td>Built-up Urban Areas</td>
<td>Sheep &amp; Lamb Fattening</td>
</tr>
<tr>
<td>Land outside Urban Areas occupied by Manufacturing or Mining</td>
<td>Dairy</td>
</tr>
<tr>
<td></td>
<td>Station Cattle</td>
</tr>
<tr>
<td></td>
<td>Pigs &amp; Poultry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Third Digit</th>
<th>Fourth Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of Idle Land</td>
<td>Amount of Land Rendered Unproductive by Weeds</td>
</tr>
<tr>
<td>Little</td>
<td>Little</td>
</tr>
<tr>
<td>Limited</td>
<td>Limited</td>
</tr>
<tr>
<td>Considerable</td>
<td>Considerable</td>
</tr>
<tr>
<td>Excessive</td>
<td>Excessive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fifth</th>
<th>Sixth</th>
<th>Seventh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Farmstead, Buildings, Plantations, Shelter, Equipment, Fences, etc</td>
<td>Kind of Native and Exotic Weeds Present</td>
<td>Size of Holdings</td>
</tr>
<tr>
<td>Excellent</td>
<td>Fern</td>
<td>Very large</td>
</tr>
<tr>
<td>Good</td>
<td>Manuka</td>
<td>Large</td>
</tr>
<tr>
<td>Medium</td>
<td>Other Natives</td>
<td>Medium</td>
</tr>
<tr>
<td>Poor</td>
<td>Gorse</td>
<td>Small</td>
</tr>
<tr>
<td>Very Poor</td>
<td>Broom</td>
<td>Very Small</td>
</tr>
<tr>
<td></td>
<td>Blackberry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wild Briar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ragwort</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other Exotic</td>
<td></td>
</tr>
</tbody>
</table>
Draft New Zealand Land Use Classification (1984)

In 1981, the then Department of Statistics established a Standard Land Use Code Committee to provide a standard code for classifying current actual land-use activity to inform a number of purposes (Standard Land Use Code Committee 1984). The committee first considered land use from a broad conceptual standpoint and identified a range of characteristics to describe land use arranged into three broad categories: parcel, structure, and space use. Parcel attributes encompassed both societal (eg, ownership, zoning) and natural (eg, area, slope, soils) characteristics. Structure included basic information about physical building characteristics. Space use included aspects of activities, ownership activities, number of household units, etc.

Following a period of public consultation, the committee determined that an activity-based approach would provide the most value. They developed a hierarchical classification to foster comparability of assessment throughout New Zealand. The classification aligned to related classifications. Manufacturing classes were directly derived from the NZ Standard Industrial Classification, while the remainder of the classification was derived from the Auckland Regional Authority. The committee pointed out a number of issues facing land-use classification such as extending the concept to include water bodies, considerations of multiple use both spatially and temporally over time and urged practitioners to record all uses observed. The classification was never formally adopted or used.

The classification used an aggregative four-digit coding system. The classes became progressively more detailed further down the hierarchy. For example, 1 = Residential, 12 = Group Quarters, 123 = a Residence Hall or Dormitory, and 1232 = boarding school dormitory. Therefore each level was limited to a maximum of 10 categories (0–9). Table 6 lists the first level of the classification. The recommended classification extended across 27 pages and included approximately 1000 categories.

Table 6
Level-one classes from the 1984 draft New Zealand Standard Land Use Classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential</td>
</tr>
<tr>
<td>4</td>
<td>Transport, Communication, Utility, Storage</td>
</tr>
<tr>
<td>5</td>
<td>Trade</td>
</tr>
<tr>
<td>6</td>
<td>Services</td>
</tr>
<tr>
<td>7</td>
<td>Cultural, Entertainment, Recreation</td>
</tr>
<tr>
<td>8</td>
<td>Resource Production &amp; Extraction</td>
</tr>
<tr>
<td>9</td>
<td>Unmodified Land &amp; Water</td>
</tr>
</tbody>
</table>
Australia-New Zealand Land-use Classification Interim Standards (1999)

In 1999 Standards Australia and Standards New Zealand published an interim land-use code standard called the Australian and New Zealand Land Use Codes (ANZLUC) (Australia and New Zealand Land Information Council 1999). The standard was not subsequently formally adopted nor used.

ANZLUC provided a standardised system for describing areas of land within a geographic information system considering: 1) simplicity and flexibility; 2) potential for expansion; 3) generality; 4) consistency within the codes; and 5) compatibility with existing systems. It defined land use as the “purpose or manner for which land is being used” (p5). Other considerations or aspects of land use, including cover, physical features, or tenure, were specifically excluded, although it was recognised that those attributes could contribute to the interpretation of land use. Users were expected to combine information on land from other sources with land-use data as needed during decision-making processes.

Similar to the 1984 classification, ANZLUC was a 4-level hierarchical classification consisting 1,132 classes at Level 4. A set of 23 auxiliary codes organised into three categories (general, agriculture, mining or extractive industries) provided information on manner of use, such as owner-occupied, extensive agriculture, or bore hole (ie, mining). The standard recommended associating more than one code for areas exhibiting multiple uses spatially (eg, service and recreation or multiple level buildings), temporally (eg, rotating crops), or both.

Table 7
Summary of the Australia-New Zealand land-use codes

<table>
<thead>
<tr>
<th>Level 1 Land use Classes</th>
<th>Number of Subclasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>Title</td>
</tr>
<tr>
<td>1000</td>
<td>Accommodation</td>
</tr>
<tr>
<td>2000</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>3000</td>
<td>Commerce</td>
</tr>
<tr>
<td>4000</td>
<td>Services</td>
</tr>
<tr>
<td>5000</td>
<td>Agriculture, Forestry, and Aquaculture</td>
</tr>
<tr>
<td>6000</td>
<td>Mining or Extractive Industries</td>
</tr>
<tr>
<td>7000</td>
<td>Protected and Recreational Area</td>
</tr>
<tr>
<td>8000</td>
<td>Transport, Storage, Utilities &amp; Communication</td>
</tr>
<tr>
<td>9000</td>
<td>Land not elsewhere classified</td>
</tr>
</tbody>
</table>
Land-use New Zealand (LUNZ) (2004)

Land Use New Zealand (LUNZ) was initially developed to provide land-use information for the Catchment Land Use for Environmental Sustainability (CLUES) project (Woods et al 2006). CLUES models the impacts on water quality at a selected point in a river network as a result of changes in land use occurring upstream. LUNZ addressed the need for a nationally consistent representation of (predominantly rural) land use.

LUNZ had three purposes:

1. Create a classification that satisfies the needs of both landscape scale models and farm-scale models
2. Determine the best estimate of land use nationally
3. Describe farms in terms that can be related to one or a mixture of MAF Monitor Farm types.

LUNZ is produced by combining information from four sources:

- **AgriBase** – a database of information collected by Agriquality to form MAF Monitor Farm models. Each Monitor Farm model is based on a survey of 20–30 farms from a particular locality.
- **Land Cover Database 2** – a national map of land cover derived from satellite imagery from 2001/2002 at nominally 1-ha spatial resolution (ie, minimum mapping unit) (Thompson et al 2003)
- **Land Resource Inventory** – a national map identifying land units with similar biophysical and land productivity characteristics (Newsome 1992)
- **Land Environments of New Zealand** – a national hierarchical classification of New Zealand’s terrestrial environments based on a combination of 15 climate, landform, and soils variables (Leathwick et al 2003a, 2003b).

In theory, AgriBase provides sufficient information to derive adequate land-use information for all farm land across New Zealand. Unfortunately, the design of the dataset had several problems that prevented it from fulfilling this function:

- Many farmers do not fill in all the attributes that are relevant to their farm enterprise, in particular the area occupied by animals is more often left blank than filled in
- For many farms the reported farm size does not agree with the computed area derived from the cadastral polygons associated with the farm, implying that many of the other activities reported on the farm do not necessarily occur within the farm boundary
- Reporting on type of farm is inconsistent and reflects either a farmer’s primary source of income or profit or alternatively the predominant area or even the preferred or dominant activity of the farmer.

The combination of these inconsistencies made it impractical to rely on AgriBase alone to determine stock units per hectare or any other management function that can be related to measures used in the MAF Monitor Farm spreadsheets. Therefore a hierarchical land-use classification was developed (figure 7), and a corresponding national geospatial land-use layer was produced using a complex algorithm that estimated the probability for different land-use types to occur at any particular location within New Zealand based on the combination of input sources listed above. Refer to Woods et al (2006) for more details about classification and land-use layer development.
Figure 7
LUNZ classification hierarchy (Woods et al. 2006, p 96)
LINZ rating valuation rules

As part of its property rating rules prepared under the Ratings Valuations Act of 1998, Land Information New Zealand (LINZ) includes assessments of land use (LINZ 2008). The assessment includes 9 attributes of information that must be recorded for every rating unit (Table 8). The system includes aspects of both land use as represented by activities and zoning and land cover as represented by various built environment attributes, for example, floor area, construction materials. The LINZ rating system therefore constitutes a multi-dimensional classification that captures multiple attributes for each rating unit.

Table 8
Land-use evaluation attributes from the LINZ property rating rules

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Definition</th>
<th>Classification Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoning</td>
<td>Primary zoning or designation of land under proposed or operative district plan</td>
<td>2 Character Alphabetic Code</td>
</tr>
<tr>
<td>Actual Property Use</td>
<td>Primary and secondary activity(ies) recorded at date of inspection</td>
<td>2 Character Alphabetic Code</td>
</tr>
<tr>
<td>Number of Units of Use</td>
<td>Total number of units on the property</td>
<td>3-Character Numeric Code</td>
</tr>
<tr>
<td>Provision for Off-Street Parking</td>
<td>Total number of formed car parks on a rating unit</td>
<td>3-Character Numeric Code</td>
</tr>
<tr>
<td>Age</td>
<td>Decade built</td>
<td>3 Character Numeric Code</td>
</tr>
<tr>
<td>Condition</td>
<td>Condition of 1) external walls and 2) roof of principle building</td>
<td>2 Character Alphabetic Code</td>
</tr>
<tr>
<td>Construction</td>
<td>Predominant materials use for 1) external walls and 2) roof of the principle building</td>
<td>2 Character Alphabetic Code</td>
</tr>
<tr>
<td>Site Coverage</td>
<td>Area over which any floor(s) extend measured to the nearest m²</td>
<td>Numeric value (m²)</td>
</tr>
<tr>
<td>Total Floor Area of the Building</td>
<td>Floor area of the principle building measured to the nearest m²</td>
<td>Numeric value (m²)</td>
</tr>
</tbody>
</table>
5 Discussion and recommendations

This project examined theoretical and practical approaches to land-use classification to support development of a geospatial land-use classification for New Zealand. Land use refers to the modification of and related activities on the land by people to sustain human life. We allocate and change land use to produce different combinations of goods and services in response to changing human needs and wants. Some changes are temporary, for example, crop rotation, while others are more permanent, for example, urbanisation. Also some consequences of land-use change or associated practices are easily observed, for example, forest harvesting, while others are not, for example, gradual loss of soil fertility through inappropriate management.

End-users clearly articulated a need for a national geospatial land-use classification and associated geospatial dataset that meet the following criteria:

- Accessible and cost-effective
- Adaptable to future needs
- Applicable to a range of issues and problems
- Comparable across scales, jurisdictions, and applications
- Coordinated across a variety of users and organisations
- Defensible to a broader audience
- Feasible to produce
- Mappable into a spatial context
- Regularly updated, at frequent enough intervals to allow meaningful change analysis
- Reproducible by other organisations and over time (i.e., continuity)
- Transparent.

The provision of a national geospatial land-use classification would help organisations undertake and fulfil a range of planning, resource management, and operational needs, and through the provision of regular updates allow them to monitor the outcomes of their activities, report on their effectiveness, and modify future policies, plans, and strategies accordingly. Put more succinctly, a national geospatial land-use classification would help organisations:

- identify the current state and benefits/impacts of land uses within their jurisdiction and compare what is happening in other jurisdictions
- understand options for possible future states and associated benefits/impacts of land use, given past, current and likely future drivers and trends
- set goals for, plan, manage, review, and report on land use to meet current needs while maintaining future options.

A review of the literature identified four broad types of land-use classifications: categorical, hierarchical, multi-dimensional, and semantic. The four types tend to fall along a gradient from simple (e.g., categorical) to complex (e.g., semantic), reflecting both the richness of classification categories and the complexity of relationships among the different land-use classes. Increasing complexity of classification requires increasing complexity and sophistication of associated data models, storage, retrieval, and depiction. While richness and complexity come at a cost, they provide the benefit of being able to reproduce simpler classifications if necessary.

When evaluated against the criteria listed above, each classification has a number of advantages and disadvantages (table 9). Categorical classifications are the simplest classifications and contain no information about relationships among classes. As a consequence they are highly accessible, applicable to simple questions, feasible to produce, and readily mappable. Conversely, categorical classifications are less adaptable without creating or deleting classes, not easily compared unless using the same set of classes, harder to coordinate especially if different users have strongly different opinions about the classes being used, and less transparent, given the often subjective nature of categorical classifications.
Table 9
Comparison of the 4 types of land-use classifications

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Categorical</th>
<th>Hierarchical</th>
<th>Multidimensional</th>
<th>Semantic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessible</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Adaptable</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Applicable</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Comparable</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Coordinated</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Defensible</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Feasible</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Flexible</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Mappable</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Reproducible</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Transparent</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
</tbody>
</table>

Hierarchical approaches depict land use as a nested set of classes in which higher levels become divided into more specific or detailed levels. Hierarchical classifications are readily accessible and understandable and, like categorical classifications, readily mappable at different levels. Theoretically, through the addition of more detailed classes, hierarchical classifications are more adaptable than a simple categorical classification. However, various studies repeatedly pointed out that hierarchical classifications suffer from ambiguity because many objects can be categorised in more than one class. Furthermore, the addition of more classes to capture additional details results in hundreds or even thousands of classes, which can complicate rather than simplify the classification process.

Multidimensional classifications store multidimensional attribute information for defined units or objects and allow recombination to generate different land-use classes. As a consequence, such classifications have greater adaptability and flexibility because additional dimensions can be added without necessarily having to reconfigure the entire classification from scratch, although the overall relationship among classes will be altered. Overall, this approach appears to offer a middle ground between simplicity and complexity.

Semantic classifications derive from linguistic theory and describe land use using a rich collection of vocabulary and syntax that together form a land-use grammar (Mayall 2002) from which different interpretations (ie, classifications) could be derived. Semantic approaches present a marked trade-off in terms of retaining information for future retrieval and use versus accessibility or usability. Such approaches require much more sophisticated approaches to data structures, storage, querying, and retrieval. If properly maintained, such approaches have the potential to allow for a wide range of sophisticated representations of land use or land resources overall.

Both international practice and previous attempts in New Zealand to establish land-use classification standards favour the use of hierarchical classifications. Yet despite over 50 years of thought and development, most hierarchical systems remain either unimplemented or partially implemented, either in terms of scope (ie, less detailed than originally intended) or durability (ie, not updated as regularly as anticipated if at all). As discussed above, they present persistent issues of comparability, continuity, ambiguity, etc. For example, Version 1 of the New Zealand Land Cover Database had to be re-classified to match the expanded set of classes used in Version 2 (Thompson et al 2003) to facilitate land-cover change analysis.

Given the long list of identified issues and limitations of hierarchical classifications, why do they persist? One possible answer is that such classifications developed during a period when...
technological and computational advances made classification beyond simple categorical maps possible. Hierarchical classifications therefore represented the next logical step from categorical classifications, going from no relationship information to the next most advanced yet still tractable manner to depict relationships among classes. While hierarchical classifications provided structure to the classification, such structures remained relatively simplistic. Such approaches were likely easier to capture and process both mentally and computationally. However, as witnessed by several of the attempts to develop New Zealand land-use classifications, hierarchical classifications can quickly become unwieldy beyond a few levels. Attempts to provide comprehensive classification systems that can cover every possible contingency result in unmanageable number of classes, for example, the 1999 ANZLUC classification with its 1132 classes (Australia and New Zealand Land Information Council 1999).

We did not find explicit information outlining the reasons why New Zealand has not yet implemented a consistent and enduring land-use classification. While organisations in New Zealand currently express a strong desire to develop better land-use information, including a geospatial land-use classification (see Appendix 2), history suggests a waxing and waning of interest. Any number of factors will likely be involved, including conceptual issues identified by others (eg, Mücher et al 1993) or operational issues (eg, lack of baseline funding for base land-use information).

From a classification standpoint, the continual fixation on developing a hierarchical geospatial classification actually hinders rather than promotes development. As discussed, hierarchical classifications attempt to partition land use into mutually exclusive categories or classes based on particular criteria and attributes. However, even at high levels the lack of sound boundary rules causes confusion and ambiguity. Further desire for changes or ‘improvements’ over time to meet emerging needs can confound attempts at stability and frustrate temporal analyses that represent one of the critical purposes of collecting land-use information in the first place. The LCDB 1 re-classification serves as a classic example.

On the other hand, implementation of even a basic classification can provide vital information and begin to fill critical knowledge gaps. Examples from Spain and the United States offer possible alternatives for overcoming limitations by moving beyond hierarchical classifications through the use of multi-dimensional approaches. The Australian ALUM classification seems well-placed in that regard and appears to have established momentum with regard to both land-use classification and the provision of associated geospatial information. However, theirs is a relatively simple, three-tier classification system and time will reveal the full extent of ALUM’s adaptability and flexibility.

Ultimately, most land-use classifications fail to live up to their expectations because they are too rigid. To paraphrase Guttenberg (1993), they fail to reveal and clarify the nature of land use and instead generate concealment and ambiguity. Consider, for example, the following descriptions of a hypothetical pastoral landscape provided by two different observers:

Observer 1 – Horse Trekking Tourist; “Sheep grazing in the pasture, with mountains in the background. Probably exotic pasture, maybe with some weeds and a few natives. Very tranquil and a beautiful vista. That would make a great picture!”

Observer 2 – Sheep Farmer; “Romney sheep, 15 stock units to the hectare, on a mixed ryegrass-clover pasture with a bit of brown top, producing ~10 tonnes dry matter/ha, top dressed annually with superphosphate @ 250 kg/ha in the spring. One grazing in the winter behind an electric fence, short-rotation summer grazing. Easy-care, set-stocked at lambing. Had an outbreak of footrot last year, treated successfully with zinc sulphate bath and selective culling. Possum numbers are down since we started control on our block of native bush, and the trees are recovering. Makes it a lot nicer to show the farmstays when they come to visit.”

Both examples provide a sense of the landscape and at a basic level provide evidence of agricultural land use targeted at sheep production. While lacking much knowledge about sheep production, Observer 1 implies a sense of the quality and visual appeal of the landscape. Observer 2 obviously supplies specific detail about various land-use activities, including critical information on temporal activity sequences (sensu Young 1994). Both provide a degree of overlapping and complementary information that would be quickly lost in applying, say, a simple hierarchical classification such as: agriculture-pastoral-sheep. A multidimensional classification could capture more detail, especially if it
catered for each activity listed by the sheep farmer (eg, top dressing, etc) but it would still fall short of capturing the full knowledge and story provided.

Instead, we want an approach that facilitates the capture and curation of as much knowledge and information as possible, in as natural a manner as possible. As considerations of landscape quality, character, and sustainability gain importance (Antrop 2005; Blaschke 2005; de Groot 2006), the concept of land ‘use’ is expanding and becoming more sophisticated. Therefore more traditional classification methods, especially hierarchical methods, represent, at best, a limited interpretation of use and, at worst, a never-ending cycle of dead-ends that require continual adjustment, reformation, or reinvention.

We therefore recommend bypassing traditional land-use classification approaches, especially hierarchical approaches, to develop a geospatial land-use classification for New Zealand, and recommend focusing on developing a semantic approach to land-use classification. The semantic approach would focus, in the first instance, on developing a semantic classification that defines key concepts and aspects of land use and ways to describe and characterise it. Such an approach would then support, in the second instance, the development of a land-use classification – or classifications – to meet a variety of needs ranging from standard international reporting to land evaluation for resource management.

The analogy to language would be: rather then developing the book (ie, the land-use classification) we instead develop the dictionary, grammar, thesaurus, ontology, and semantics of a land-use language, from which we write different books (classifications) to suit different needs while retaining the ability to translate among, compare, and contrast different books.

We see a number of key advantages to such an approach including:

- Adaptable and expandable – a semantic classification only requires as much information as is currently available but can grow organically as the knowledge and language of land use develops
- Additive rather than restrictive, ie, forward-thinking, not restricted by past definitions of land use or how derive it
- Reproducible – able to retain and reproduce past classifications, provided you maintain the dictionary and thesaurus
- Flexible – still allows generation of other classification types
- Understandable – by both humans and computers
- Facilitate comparisons – semantic approaches are already used to compare classifications.

More specifically we recommend a two-stage approach to development of a semantic geospatial land classification including:

**Short-term (ie, within 1 year)**

- Initiate a process to identify different sources and owners of land information within New Zealand and from that identify the categories or attributes of available land information that could form the basis for a semantic land classification
- Develop specifications for a simple, first-generation semantic classification that includes provisions for generating a geospatial land-use layer to meet the most urgent or important needs as identified by a range of users
- Begin to link information from various sources to the new classification to produce a first generation geospatial land-use layer for use by a range of practitioners.

**Longer term (2–3 years and at regular appropriate intervals thereafter)**

- Develop full specifications for a semantic land-classification system that integrates many elements of land information from different organisations across New Zealand including land use/activity, land cover, land ownership/property rights.
From our own research and as a result of this project, we know that New Zealand is well-placed to develop a semantic geospatial land-use classification. New Zealand already possesses a rich set of land information (e.g., Land Resource Inventory, Land Environments of New Zealand, Land Cover Database, Protected Areas Network, Valuation Data, Agribase, regional and local council information, etc.) that would provide a strong foundation for such a classification. If brought together, that information would provide a detailed picture of the state of New Zealand’s land, including land use, and would represent a quantum leap forward compared with other international land-use classification systems.

In making these recommendations we must stress two points. First, a semantic approach represents a more difficult and long-term pathway compared with more traditional approaches. It will require more significant commitment and investment than appears to have occurred in the past within New Zealand. Second, defaulting to what appears to be a simpler classification is not necessarily simpler. Construction of apparently simpler classifications like hierarchical classifications can be as complex as constructing apparently more complex classifications like a semantic classification. Further development of the simpler classification always results in the loss of information that creates challenges for on-going or future use. Often it requires recovering or re-collecting supplemental information to restore what was lost. This is particularly true for complex concepts like land use, where emerging demands quickly eclipse the information contained in simple classifications. A forward-thinking approach would seek to avoid or minimise such limitations as much as possible.
Appendix 1
End-user needs questionnaire
GEOSPATIAL LAND USE CLASSIFICATION
USER NEEDS QUESTIONNAIRE

Definitions

*Land information* – knowledge about the state of the land including its cover or use

*Land cover* – physical condition of the land

*Land use* – cultural, economic, or social activity(ities) or function(s) for that land supports. Land can have more than one use.

NB. Please complete the fields marked with an asterisk.

PART A.  BACKGROUND

1. Are you prepared to have your name published in the final report*? ☐ YES ☐ NO

2. Name*:

3. Postal Address*:

4. Phone:

5. E-mail*:

6. Address:

7. What is the name of the organisation you are representing (if any)?

8. Which of the following best describes the sector you are representing?

☐ Central Government
☐ Local Government
☐ Crown Entity
☐ Private Sector
☐ Academic
☐ Community Group
☐ Other, please specify
PART B.  LAND INFORMATION

9. How important is **land information** to your organisation and why?

10. What are some of the major uses of **land information** by your organisation?

- [ ] Property Administration
- [ ] Resource Management
- [ ] Support the Treaty of Waitangi
- [ ] Environmental Reporting
- [ ] Policy Analysis
- [ ] Socio-economic
- [ ] Education/Training
- [ ] Asset Management
- [ ] International Obligations
- [ ] Statistics
- [ ] Trade/Business
- [ ] Community/family services
- [ ] Tourism
- [ ] Transport
- [ ] Defence/security
- [ ] Education
- [ ] Other(s), please specify

11. Does your organisation consider **land information** when undertaking activities or functions required by the following laws, regulations, rules, and/or management policies?

- [ ] Resource Management Act 1991
- [ ] Local Government Act 2002
- [ ] Electoral Act 2001
- [ ] Cadastral Survey Act 2002
- [ ] Statistics Act 1975
- [ ] Kyoto Protocol
- [ ] Other(s), please specify:
PART C. LAND COVER

12. How important is land cover to your organisation and why?

13. In what ways does your organisation use land-cover data?

PART D. LAND USE

14. How important is land use to your organisation and why?

15. What are your organisation’s information needs for land use?

16. What are the biggest obstacles for your organisation in addressing land-use challenges?

17. What current types of data, information, approaches and tools does your organisation use in trying to characterise land use?

18. What additional types of data, information, approaches and tools would most help your organisation in addressing land-use issues?

19. Would your organisation benefit from the development of a land-use classification? □ YES □ NO. If yes, please explain the potential benefits to your organisation.

20. What types of land-use attributes, classes and level of detail does your organisation require to fulfil its roles and functions?

21. In your opinion, the three most important things needed to improve the scientific and technical basis for evaluating, monitoring, managing, and enhancing land use are the following:

   1.
   2.
   3.

GENERAL COMMENTS

22. Please feel free to make any other comments here that have not been covered elsewhere in the questionnaire.
Appendix 2
Land-use classification end-user needs assessment

Part of the research consisted of assessing the land-use information needs of New Zealand. A questionnaire (Appendix A) was designed to provide key stakeholders with the opportunity to contribute to the development of specifications for a geospatial land-use classification for New Zealand. Detailed input from stakeholders and communities of interest was required to help identify current land-use problems and elements for a land-use classification. Participation in the questionnaire was voluntary and consisted mainly of open-ended questions.

The user-needs questionnaire was emailed to 100 key stakeholders. Only 19 key stakeholders chose to respond. The following section provides a summary of the key themes that emerged. Many summaries are followed by selected comments from some respondents.

Sector representation

Of the 19 respondents, many came from local government, with a mix from central government, the private sector and a few Crown entities (figure 8). No responses were received from academia or community groups. ‘Other sector’ representation refers to an Officer of Parliament, while the Parliamentary Commissioner for the Environment is independent of the Executive Government.

Figure 8
Sector representation
Major uses of land information

Respondents were asked to select boxes that highlighted some of the major uses of land information within their organisation. These were identified as environmental reporting, policy analysis, resource management and socio-economic work.

Figure 9
Major uses of land information
Importance of land information

Respondents were asked to comment on the importance of land information to their organisation. Land information is considered overall VERY IMPORTANT by the respondents for the following key reasons:

- Legislative requirements (national and international)
- Policy Development
- Planning requirements
- Environmental Reporting
- Monitoring land trends – changes in cover or use of the land
- To assist with day-to-day running of farms
- Biosecurity management responsibilities (animal and plant pests)
- Resource management.

“To meet business and legislative requirements, and to support strategic outcomes and operational outputs.”

“Nearly all environmental and physical resource management issues are either directly or indirectly related to the use of land.”

“Extremely important! Basic building block of city planning.”

“Land information is essential to New Zealand meeting its international obligations, in particular the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Land information can be used to identify jurisdictions, areas of responsibility and pinpoint responsible organisations and individuals. It is a key component in being able to manage, monitor and govern the country’s rural resources effectively and is an important component of state of the environment reporting, at both the regional and national levels.”
Importance of land-cover information

Respondents were asked to comment on the importance to their organisation of land-cover information. Land cover is considered overall VERY IMPORTANT by the respondents for the following reasons:

Land-cover provides a statistical account of the composition of the landscape (ie, what types of land cover characterise New Zealand)

Land-cover information is a critical data source for meeting national and international reporting obligations including:

- OECD
- Kyoto Protocol
- FAO
- UNFCCC
- State of the Environment
- Land cover is important in being able to manage, monitor and govern the country’s resources effectively
- Base data for central and local government biosecurity responsibilities.

“Land cover in terms of differences within and between ecosystems (such as differences in terrestrial indigenous vegetation) is vital for a variety of environmental objectives”

“Land cover relates to productivity and to environmental factors such as flooding and soil loss.”

“Land cover has a major impact on sustainable resource management, especially of land and water.”

“One of the 3 pillars of understanding the land resource: land use/land cover/landform”

Respondents were asked to comment on some of the ways in which their organisation used land-cover data:

- Policy development, monitoring and validation (eg, RMA, Climate Change)
- Natural heritage management
- Central and local government sustainability objectives
- Operational analysis and modelling (eg, impacts from erosion)
- Wildfire threat analysis
- Habitat and pest identification and management
- Biodiversity and ecological inventory and analysis, planning and monitoring
- Monitoring land-use change
- Pest and disease management.
Importance of land-use information

Respondents were asked to comment on the importance of land-use information to their organisation. Land use is considered overall VERY IMPORTANT by the respondents for the following key reasons:

- **Characterisation** – demonstrate urban and rural characteristics of New Zealand
- Fire Risk Assessment
- **Modelling** – land-use change scenarios
- **Monitoring** – effects of land use on the environment, land-use trends
- **Policy & Planning** – provide baseline information to manage New Zealand’s land resources
- **Reporting** – environmental indicators for State of the Environment reporting
- **Resource management and strategic planning** – assess the implications of different land use and the positive and negative effects on the environment.

“Land use information serves as a tool used to forecast livestock numbers, evaluate carrying capacity, evaluate change potential, monitor and forecast carbon emissions, as well as model economic impacts.”

“Critical for many of the regulatory processes. It is also a mandatory set of data for Rating Valuations.”

“Assessing risk of fire. People usually start fires, equipment also but this is less likely due to regulations around buildings and storage of substances. Natural events happen but are few. We add the information of events each year to confirm what we identify as risk/hazard are true. And adjust our thinking to these results.”
Information needs for land use
Respondents were asked to comment on some their organisations’ information needs for land use. Organisations use land-use information to identify land-use change (past, present, future trends) and to identify what implications land-use change has on New Zealand’s environment, social, economic and cultural domains, including:

- Emergency response
- 4 Fs – forestry, fisheries, food and farming requirements
- Land, air, water quality management
- Local and national strategic planning
- Monitor and mitigate disease or pest incursions
- National and Local Environmental/Sustainability reporting
- Policy development
- Rating information
- Resource Management Act requirements
- Statutory land management
- Urban/Rural operational analysis and modelling – to answer such questions as: what was there, what has gone, what has changed, and what can we expect in the future.

“Assessing the impacts of Global Climate Change on the potential for various types of land use”
“Changes in land use can be used to explore the effect on things such as potential sediment or contaminants through modelling. The base information is required as well as predicted changes.”
“We can not levy property rates unless we have a District Valuation Roll. Land use (both current use and best future use) is a mandatory field on the Roll. If it is not recorded and maintained, we would not be allowed to assess rates.”
“Need land use and land management information, ideally at a paddock level, to link to land and water resource management issues and solutions.”
Biggest obstacles for organisations in addressing land-use challenges

Respondents were asked to identify the biggest obstacles for their organisation in addressing land-use challenges. These were as follows:

- **Access**: Organisations do not have access to a nationally significant land-use dataset. The availability of complete and current land-use data. Organisations do not have access to land-use data that are current and regularly updated at a national scale.

- **Classification**: New Zealand lacks a nationally consistent land-use classification scheme that meets the needs of multiple agencies.

- **Cost**: Cost effective availability of land-use information.

- **Leadership**: There is a "lack of national commitment to the regular capture of land-use information". It is seen to be "ad hoc and not conducive to the rigorous annual planning, monitoring and reporting activities" that are being undertaken within New Zealand.

“Lack of updated data on land-use changes for non-consented activities.”

“...accuracy, consistency, sharing, resources and leadership.”

“Understanding and changing land-use behaviours. Gathering and maintaining quality data and information. Meeting the needs of multiple agencies.”
Current data and tools used to characterise land use

Respondents were asked to identify the current types of data information, approaches and tools their organisation uses to try and characterise land use. These are as follows:

Data/Information
(Note: listed alphabetically; organisations tend to use and combine these datasets in a variety of ways):

- AgriBase
- Building Consent Data
- Census / Agriculture Production Survey
- City/District/Regional Plans
- CLUES Data
- KiwImage (Satellite Imagery)
- Land Cover Databases (LCDB1 & LCDB2)
- Local Knowledge
- NZ Land Resource Inventory (NZLRI)
- Orthorectified aerial photography
- NZTopoOnline
- Valuation Data
- Vegetation Data.

Tools/Approach

- Combining data layers via GIS and extracting land-use information from the variety of datasets
- Digitising using GIS
- Satellite imagery and aerial photography interpretation
- Site visits, GPS and field checks
- Other tools being used to capture, store, analyse land-use information include
  - ArcReader (free desk-top mapping application)
  - ER Mapper (image compression and manipulation application)
  - Microsoft Excel (spreadsheet application)
  - Microsoft Access (database application).
Additional data, information, approaches, and tools required to address land-use issues

Respondents were asked to identify what additional types of data, information, approaches and tools would most help their organisation address land-use issues. The key trend was identified as an integrated land (land use & land cover) information system applicable across the entire country.

A land-information dataset that consisted of land use and land cover would be required to be updated nationally at regular intervals and meet standardised terminology to describe a combination of land-use and land-cover characteristics.

Organisational benefits from a land-use classification

Respondents were asked to identify whether their organisation would benefit from the development of a land-use classification and, if they did, to explain the potential benefits. All 19 respondents agreed their organisation would benefit from a land-use classification.

But the real usefulness for organisations is not simply the creation of a reliable/competent land-use classification, but rather the development of a spatial land-use dataset derived from that classification. Some of the benefits such a land-use classification would bring were listed by the respondents as follows:

- **National consistency** – communicate in a consistent context with a variety of key stakeholders
- **Reporting** – help meet local, national and international obligations
- **Comparison** – compare land-use data at national, regional and local levels
- **Change** – clearly identify and monitor land-use change
- **Current** – regular versions of land use would ideally be made available
- **Coordination** – reduce duplication of data capture where possible, and compile unique datasets collected for individual requirements either physically or virtually into a single dataset.
Land-use classification information
Respondents were asked to identify the types of land-use attributes, classes and levels of detail their organisation would require to fulfil its roles and functions. Some common suggestions were:

- Provision of links to or examples of international land-use classification that provide examples of good practice, including the National Land Use Database (UK), the USGS land-use and land-cover classification (USA), and the Anderson land-use and land-cover classification system (USA).

- More detailed land-use information to create land-use maps and analyse statistics for monitoring purposes. For example, farming activities such as horticulture should identify crop type. Biodiversity information should identify habitat type, wetland description, vegetation type, etc.

- A high level of detail in relation to rural, commercial, residential, industrial and recreational uses, population present, soil/water quality, significant features, and utilities.

- Data should have very high spatial and thematic accuracy that can be applied at a wide range of scales but only need to consist of several primary classes.

- Functional, physical and cover attributes of an open system of classes capable of hierarchical use and of capture and processing at site scales and regional scales.

- The ability to map and identify the trends of land use.
Three most important things needed to improve land-use information

Respondents were asked to list the three most important things needed to improve the scientific and technical basis for evaluating, monitoring, managing and enhancing land use. The top three were:

- **Accuracy**: The land-use classification needs to be meaningful and relevant and consist of clear, national classification units. To achieve greater accuracy, land-use classification may need to concentrate on the more important applications of land-use data, reduce the number of classes, and use improved imagery and classification techniques.

- **Maintenance**: Land use changes constantly, therefore robust maintenance processes must be in place to monitor change and update the dataset on a national scale. Appropriate governance and infrastructure would be required to support the development and on-going maintenance of the land-use classification.

- **Collaboration**: Many organisations have different needs, at different levels, for land-use information. Organisations may have the technical expertise and/or funds to contribute to the land-use initiative, and/or be able to supply some necessary data. The data collection of a national land-use dataset needs to be centralised.
General comments
Respondents were asked for other comments they had not been able to make elsewhere in the questionnaire. Some key thoughts were:

- To achieve the development of a land-use dataset organisations could feed their own data into the land-use model, for example, AgriQuality has AgriBase, DOC has wetland datasets, Statistics NZ has the AgCensus, Landcare Research has LENZ, etc.
- GIS practitioners often combine their spatial data thinking of land use and land cover.
- The land-use classification “needs to be designed by practitioners not scientists” to ensure the outcome of the data capture according to the classification is useful.
- The development of a land-use classification needs to consider information based on imagery (eg, land cover via LCDB) and information from an operational land-use perspective (eg, stock numbers, fertiliser use via Agribase or consents).
- The development of the land-use classification categories should be aligned to the MAF monitoring reports so that everything fits together and gives some consistent meaning to the dataset.

One respondent recommended further investigation into the Anderson Land Use Land Cover Classification System for use as a template in New Zealand. This classification system effectively combines both characteristics of land use and land cover into a single classification scheme.
References


