Harmonisation of land-use class sets to facilitate compatibility and comparability of data across space and time

Louisa J.M. Jansen
Land/natural resources consultant, Via Girolamo Dandini 21, 00154 Rome, Italy
Tel.: +39-065757719, E-mail: Louisa.Jansen@tin.it

Abstract

Harmonisation of land-use class sets should consider both space and time, as the objective should include harmonisation of land-use change in order to analyse environmental processes and problems. Existing systems make only a limited contribution to data harmonisation and data standardisation as they contain many inconsistencies in the adherence to the fundamental principles of classification and use a variety of basic units of measurement, in addition to the lack of agreement on the definition of land use. Though the meaning of land use varies among sectors, the set of key parameters used is limited. Analysis of major existing class sets reveals that two parameters suffice: function that describes land use in an economic context and activity that is defined as the combination of actions resulting in a certain type of product.
An example of land-use harmonisation in Albania illustrates how the creation of a reference system based upon the principles of classification, using the synergy between classification and information technology concepts and based upon the function and activity parameters can facilitate harmonisation between land-use class sets in parallel to achieving land-use change harmonisation. Comparison with remotely sensed based land-cover related land-use data illustrates that land use contains many aspects that go beyond land cover. Land-use change operates over a range of scales in space and time and analysis at different levels of data is necessary in order to detect the patterns at the different data levels.
The way forward to harmonisation of land-use class sets is adoption of a parametric approach. Further research is necessary to define quantitative measures for the harmonisation result at class level and between two class sets.

Keywords: Land use; Land-use change; Classification; Data harmonisation; Data standardisation.

1. Introduction

Land-use change knowledge has become increasingly important in order to analyse environmental processes and problems, such as uncontrolled urban development, deteriorating environmental quality, loss of prime agricultural lands, expansion of agriculture into areas that comprise either fragile ecosystems (e.g., wetlands and steep lands) or a high value with respect to biodiversity (e.g., humid tropical forests) or areas with a high incidence of diseases (e.g., malaria, river blindness). These processes and problems must be understood if living conditions and standards are to be improved or maintained at current levels (Anderson et al., 1976; Dumanski and Pieri, 2000). Land-use change, as one of the main driving forces of (global) environmental change, is central to sustainable development (Meyer and Turner, 1994; Walker et al., 1997; Walker, 1998; Lambin et al., 2000). It is, therefore, essential to have detailed and in-depth knowledge of not only land-use processes and problems but also of land uses. Such information is required at multiple scales as support at the local, regional, state and cross-border co-operation levels.

Nowadays emphasis is shifting from static land-use data collection towards more dynamic environmental modelling in order to understand the past, monitor the present situation and to predict future trajectories (Lambin et al., 2000; McConnell and Moran, 2001; Dolman et al., 2003). This implies the importance to re-examine existing land-use data sets and attempt to harmonise them to make comparisons within and between countries and to compile time series with which to analyse the change dynamics and detect trends. Data harmonisation will be required as it is unrealistic to work only with new standardised class sets, with major financial and intellectual investments having been made in existing class sets and survey programmes that use established methods of classification (Wyatt et al., 1997; Wyatt and Gerard, 2001).

The Land Use Cover Change (LUCC) programme element of the International Geosphere-Biosphere Programme (IGBP) and International Human Dimensions Programme on Global Change (IHDP) mentioned in their science/research plan (Turner et al., 1995) that classification and data are a cross-cutting integrating activity for which data availability and data quality need to be analysed and a classification structure suitable for various requirements need to be devised. In addition, McConnell and Moran (2001) highlight two key issues:

- Both space and time considerations are essential for making land-use data compatible and hence comparable.
- Harmonisation of land-use classifications includes harmonisation of land-use *change,* as we need to understand land-use change processes for decision making as explained above.

Therefore, any discussion on harmonisation of land-use class sets should address not only existing or proposed classifications but also data quality, space and time dimensions and land-use change.

In this paper the harmonisation of land-use class sets, or correspondence between land-use class sets, will emphasize the semantic aspect of class sets consisting of the class definitions as these imply the parameters used in the formation of classes. Class descriptions contribute to the definition of boundary conditions that should be applied unequivocally and consistently when establishing correspondence between classes belonging to different class sets in order to avoid errors in data interpretation. The level of confidence with which such class correspondence is established is highest when the same parameters have been applied; differences in the applied parameters, and thus in boundary conditions, produce lower confidence levels. Complete correspondence is not always obtainable when harmonising data, thus there is a need to establish rules in order to reach the highest level of confidence possible.

2. Definition of the domain of interest

2.1 Land use

An international agreement on the definition and classification of land use does not exist though many attempts have been made (Guttenberg, 1965; IGU, 1976; Kostrowicki, 1977 and 1980; UNEP/FAO, 1994; Baulies and Szejwach, 1998; Duhamel, 1998; McConnell and Moran, 2001; Jansen and Di Gregorio, 2002). Consequently, a common terminology is lacking. The term “land use” has different meanings across disciplines and, as a result, implies a set of mostly unidentified parameters. These different perspectives on land use are, however, all valid. In the context of this paper land use is defined as “*the type of human activity taking place at or near the surface*” (Cihlar and Jansen, 2001).

Land use is determined by natural, economic, institutional, cultural and legal factors. In general, possible land uses are limited by biophysical constraints. These include climate, topography, soils and the geological substrate, presence or availability of water and the type of vegetation. Agricultural practices differ from one region to another and different types of land uses are practised on the same type of land in different areas, depending on the history, local traditions and way of life, apart from the biophysical constraints (Cihlar and Jansen, 2001). The location of an area with respect to other types of land uses, such as residential and industrial areas, is also an important factor (e.g., the location of a commune close to main urban centres and its proximity to, for example, an airport) (Jansen, 2003). Economic incentives as part of policy (e.g., the EU Common Agricultural Policy) can affect land-use patterns.

2.2 Classification

Classification is defined as "*the ordering or arrangement of objects into groups or sets on the basis of relationships. These relationships can be based upon observable or inferred properties*" (Sokal, 1974). Thus, classification denotes a process. The term "classification" embodies two meanings (Duhamel, 1998): (1) establishment of groupings of all objects in a given field (according to Sokal's definition); and (2) using the established groupings in order to decide the membership status of other objects (e.g., in remote sensing the imagery is used for the identification process of objects). The term "classification system" includes not only the definition of the domain investigated and the classification process of the objects, but also a considered set of principles, or methodology, to assign individual land uses to land-use classes and these are arranged according to a set of adopted rules. Furthermore, it includes information for evaluating the reliability of assignment of objects to the various classes. Not only the quality of the data should be documented, but also the quality of the harmonisation.

Classifying all the objects in the domain of interest requires some basic principles, which have been described in detail elsewhere (e.g., EUROSTAT, 1991; UNEP/FAO, 1994; FAO, 1997; LANES, 1998; Duhamel, 1998; Jansen and Di Gregorio, 1998; Di Gregorio and Jansen, 2000). The key principles are:

- Completeness and absence of overlap of classes;
- Existence of definitions and explanatory notes;
- Existence of an index of objects;
- Spatial and temporal consistency; and
- Independence from scale and data collection tools.

Since many existing classifications and map legends do adhere only in part to these principles, as will be demonstrated later on, the use of the term "class sets" has been preferred in this paper.

2.3 Data standardisation and data harmonisation

Data standardisation is defined as "*the use of a single standard basis for classification of a specific subject*", whereas data harmonisation is defined as "*the intercomparison of data collected or organised using different classifications dealing with the same subject matter*" (McConnell and Moran, 2001). The understanding between data standardisation and data harmonisation is fundamental:

- Data standardisation will allow direct comparison of class sets but would disregard the financial and intellectual investments made in established methods and data sets; and
- Data harmonisation will allow countries and institutions to continue to use existing data systems and classifications but when definitions are imprecise, ambiguous or absent problems arise. Moreover, if many class sets are involved the number of pair-wise class combinations becomes excessive because comparison of n data sets requires $n(n-1)/2$ comparisons to be made.

The problem of excessive pair-wise class combinations can be resolved by developing a common reference system. Correspondence between classes may then be inferred from the explicit record of how each class relates to the reference system. The advantage is that translation of class sets into the reference system would be required just once. In addition, such a reference system would be well suited to form the basis for a generally accepted classification that could be promoted as future standard. At the same time a reference system could form the sound basis for a data model for use in geo-databases needed to manage information on land (Wyatt et al., 1993; McConnell and Moran, 2001; Jansen et al., 2005b).

3. Previous attempts at land-use harmonisation and standardisation

An important effort for establishment of an international recognised statistical system was made by the United Nations Statistical Division with the publication of the International Standard Classification of all Economic Activities (ISIC) in 1948 with three major revisions in 1958, 1968 and 1989 (UN, 1989).

The International Geographic Union established the Commission on World Land-Use Survey in 1949 (IGU, 1976). A legend for a world map at a scale of 1:1,000,000 was developed combining land-cover characteristics with function. This scale was quickly abandoned in favour of national land-use surveys at much larger scales in Great Britain, Italy, Japan, Malaysia, Poland and Sri Lanka. Furthermore, the IGU established the Commission on Agricultural Typology that tried in the period 1964-1976 to produce a system dedicated to agriculture. The work of this Commission was discontinued after 1976 though some of its members continued and completed the Types of Agriculture Map of Europe in 1983 (Kostrowicki, 1977, 1982 and 1984). Contacts with FAO were made in the early 1970s when the interest in a world agricultural classification increased due to the growing food crisis. In 1983, Kostrowicki proposed a land-use classification system, including non-agricultural land uses, which was a prime mover behind a proposal to UNESCO in 1987 for a world land-use map (Kostrowicki, 1980, 1983a and 1983b). However, nothing came of it.

The American Society of Planning Officials identified different dimensions of land use at an early stage (Guttenberg, 1959 and 1965). Guttenberg (1965) also identified different "modes" for classification: referential, appraisive and prescriptive (Figure 1). However, most of the existing classifications remain in the referential mode, as it is the most neutral one, and frequently deal with observable characteristics, such as land cover and actual activity, and derived characteristics, such as function and legal aspects. The appraisive mode casts land use in the light of social interests and values that differ according to local prevailing customs.

Insert Figure 1.

In the period 1969-1971, a study was made by the Commission on Geographic Applications of Remote Sensing of the Association of American Geographers. The results were published in 1971 by Anderson and further elaborated in 1976 (Anderson et al., 1976). This remote sensing driven classification was based upon the World Land-Use Survey system (Paludan, 1976) and evolved in the period of the first LANDSAT launch. The system represents the traditional subdivision in land-use terminology for built-up and agricultural lands, and land-cover terminology for natural vegetation, water, snow and ice.

The Economic Commission for Europe of the United Nations proposed a Standard International Classification of Land Use that would allow comparison of national land-use statistics (ECE-UN, 1989). However, this is a mixture of land-cover and land-use terminology and the classes are not exhaustive.

The interest in reviewing and updating the U.S. Standard Land-Use Coding Manual (Urban Renewal Administration, 1965) led to the initiative of the Land-Based Classification Standards (LBCS) project, co-ordinated by the Research Department of the American Planning Association in corporation with several U.S. departments and agencies (APA, 1999). This effort is based upon recognition of various categories in which land use is traditionally classified: activity, function, structure-type, site development character and ownership. These categories have each there own set of characteristics and classification takes place across these multiple categories. The effort addresses many of the problems that previous systems had but remains at the level of a system divided into several descriptive classes. The choice of categories may be disputed.

The Land Utilization Type (LUT), as developed by FAO in the Framework for Land Evaluation (FAO, 1976) and in the Guidelines for Land-Use Planning (FAO, 1984), has been widely used as a generalised description of agricultural land use in terms of inputs, two levels only, and outputs for which suitability could only be defined imprecisely. This concept was based upon a shortened list of the land-use variables identified by the IGU, the difference being the application of a qualitative land-use description in the Framework. The concept was too imprecise to be applied at farm level or for production planning, it contained only one (plot) level and reflected more a potential than an actual land-use class, while being qualitative in nature. One should note, though, that this concept was adapted to the requirements of a land evaluation system and as such, it has been used in numerous regional or district crop suitability, capability and pre-feasibility studies (pers. comm. F.O. Nachtergaele, FAO). The matching of potential agricultural land uses with the land through a series of decisions and ratings yielded into a quite complicated expert system, thus the methodology became the reverse of being transparent. In the late 1980s, at FAO attempts were undertaken to improve the LUT concept. The matching of precisely defined qualities and characteristics of the land unit with broadly, usually qualitative LUTs resulted in the limited use of the quantitative land resource data. A series of FAO commissioned studies was initiated as well as collaboration with UNEP (Remmelzwaal, 1989; Adamec, 1992; Mücher et al., 1993; UNEP/FAO, 1994; ITC/FAO/WAU, 1996; Wyatt et al., 1998). Adamec (1992) was the first to define the land-use type as "*a series (or sequence) of operations (or activities) carried out (or undertaken) to produce (or harvest) products or benefits for consumption or sale*" but he recognised at the same time the difficulty to apply individual operations or their sequence and dates of execution as parameters plus the inputs already employed. Nonetheless, this definition was adopted by the ITC/FAO/WAU effort resulting in the Land-Use Database (1996). In this database, the primarily agricultural land-use class is independent from scale, the basic unit being the plot. The database permits user-defined hierarchical structures, comparison, and a number of standardised parameters are included. However, the database allows users to add or change parameters and definitions along with the order of parameters to fit a specific aim. If the objective of classification is a contribution to data harmonisation and data standardisation, another approach should be selected. The study by Wyatt et al. (1998) was an effort at outlining the parameters to be used for globally applicable definition of land uses. The idea of analysis of existing systems in order to extract the set of parameters to be used for building a reference system would have been valid if existing classifications were used. However, the analysis was based upon a number of legends, hence indicating gaps in the completeness of land-use classes and parameters used. Duhamel (1998) clearly identified that the above-mentioned studies and some selected national class sets suffer from the lack of systematic analysis of what defines land use, in addition to the insufficient adherence to the fundamental principles of classification mentioned earlier (Table 1).

Insert Table 1.

The current view of the way forward is to promote a *parametric approach* to classification. The explicit use of quantitative parameters will facilitate harmonisation between class sets if the same set of parameters is used. In many existing class sets one will find (Jansen and Di Gregorio, 2002):

- Inconsistent application of land-cover or land-use parameters, i.e. land-cover parameters are being used to distinguish land uses and vice versa;
- Inconsistent use of parameters at same level of classification, i.e. in one category a certain parameter is used and in a related category a completely different one is used;
- Use of different parameters between classes, i.e. for subdivision of a class into three subclasses more than one parameter is used; and
- Use of non-inherent characteristics, i.e. using characteristics that are not related to the subject but describe, for instance, its environment (e.g., climate, physiography, altitude from a DEM, etc.).

Although the underlying reasons for making subdivisions based upon different parameters may be valid, they show that parameters do not always have the same weight in making distinctions. Such decisions are usually not well-documented in the accompanying reports of the class sets. This hampers harmonisation of class sets, as re-interpretations of not well-documented decisions are likely to differ between persons within one country and between countries. The actual class sets make an insufficient contribution to data harmonisation and standardisation. Efforts to increase harmonisation and standardisation do not necessarily lead to loss of pragmatic decisions on the choice of parameters as the focus should be on the logical and functional consistent application of a set of inherent land-use parameters that are clearly separated from non-inherent parameters (Jansen and Di Gregorio, 2002; Jansen, 2003).

However, if an international agreement on the definition of land uses will not be reached and a common terminology found, data harmonisation will remain an impossible task, let alone attempting data standardisation. It is therefore important to underline commonalities in the existing approaches and identify a set of commonly used parameters in the class sets.

4. Major parameters for harmonisation of class sets

An analysis of several existing class sets shows that statistical data are often collected on the basis of economic purpose and/or activities (ECE-UN, 1989; UN, 1989; UN, 1998), natural resources related disciplines tend to amalgamate land-cover characteristics with activity or function (Anderson, 1976; IGU, 1976; CEC, 1995; FAO, 1998), while legal aspects are described by land rights or patents and other related legal conditions (FAO, 1998; UN, 1998). Table 2 provides an overview of the most commonly used major parameters applied by various international systems. “Function” refers to economic purpose, “activity” refers to a process resulting in a similar type of products, “biophysical” refers to the material and immaterial environment (e.g., vegetation, land cover, geology, etc.) and “legal” refers to the context of existing laws and regulations.

Insert Table 2.

Table 2 shows that the major land-use parameters utilised by sectoral class sets are limited. Though the meaning of land use varies widely among sectors, the set of major parameters is apparently not so broad. Just two parameters suffice to describe any land use: *function* and *activity*. The function approach describes land uses in an economic context. This type of approach answers the aim of land uses and is commonly used in sectoral land-use descriptions (e.g., agriculture, forestry, fisheries, etc.). The approach is able to group land uses together that do not possess the same set of observable characteristics but serve the same purpose, the so-called polythetic view (Sokal, 1977). An example of such land uses is “agriculture” that may come in many forms, dealing with plants or animals, related to extraction, production or service characteristics. These “agricultural” land uses share a large proportion of characteristics but do not necessarily agree in any one characteristic (e.g., bee-keeping versus annual rainfed maize cropping). The activity approach describes what actually takes place on the land in physical or observable terms. Activity is defined as “*the combinations of actions that result in a certain type of product*” (UN, 1989) and refers to a process. The term “activity” does not mean that one needs to witness the activity as observer at the moment that it is being carried out, but one may observe the results and infer the activity. It is important to note that the function approach is independent of the activity approach: a variety of activities may serve a single function (e.g., both farm housing and farming activities serve agriculture).

Widely known and used systems for economic activities are: (1) the 3rd revision of the International Standard Classification of all Economic Activities (ISIC) of the United Nations Statistical Commission (UN, 1989) (Table 3), which ensures harmonisation with other main economic classifications, such as the Central Product Classification (UN, 1998) (the CPC was developed for the purpose to measure outputs, i.e. products and services. Each category is accompanied by a reference to the ISIC class where the output is mainly produced (industrial origin parameter), classification of products is based on the physical characteristics of the goods or the nature of services rendered); and (2) the Nomenclature des Activités de la Communauté Européenne (NACE rev. 1) of the Commission of the European Communities, which first two levels are compatible with ISIC (CEC, 1993).

Insert Table 3.

The usefulness of the function and activity parameters is apparent. Function groups all land used for the same economic purpose independent of the type of activities taking place, whereas activity groups all land undergoing a certain process resulting in a certain type of product that may serve different functions. The result of a combined approach will be a flexible data set where re-grouping of parameters can take place for a wide variety of queries.

The level of data collection increases notably from the function to the activity concept. The use of the function parameter as first level parameter is also a pragmatic choice as most major functional groupings can be detected with limited investment of human and financial resources, whereas the activity parameter would require substantial investments in data acquisition.

5. Basic units of measurement

Land use lacks a common unit of analysis, the so-called basic unit of measurement. The definition of the this unit differs according to the purpose of data collection and/or analysis. Sometimes a statistical sample area is used, sometimes the unit is based upon mapping units at a particular scale (e.g., minimum mapping unit in the case of thematic mapping) and sometimes the cadastral parcel unit is used. These three basic units of measurement are discussed in more detail below.

5.1 Cadastral land parcel

In many countries, the smallest land unit that one can define coincides with the cadastral land parcel unit, which is the lowest-level unit of the cadastre and thus has a legal status. In the cadastral system not only the spatial extent of these land parcels is recorded and their ownership but often also the occurring land-use or land-cover related information (e.g. arable land with building). In order to have a flexible approach in which different units of measurement can be aggregated, the cadastral land parcel can be selected as the basic unit of measurement for land use. These cadastral land parcel units can be regrouped according to ownership, by cadastral zone and by the various levels of administrative units (e.g., village, commune or district level). Furthermore, the land parcel units may be regrouped according to similar type of uses and socio-economic properties in order to identify land-use systems (e.g., if the different cadastral parcels are grouped at the level of ownership and/or leasing, the level of a socio-economic unit can be reached in which also the availability and use of technology can be incorporated).Thus, there is flexibility in the use and regrouping of the data that will serve different levels of decision making in land-use planning and policy. Another advantage is that land-use change analyses will be possible at a level that corresponds with decisions made by the individual landowner or landholder.

Land registration and the cadastre need to be seen as part of the process of natural resources planning and management. They deal with two of the world's major resources, i.e. land and information. Land information is necessary in many government activities. The registers may be used for land taxation, the rights over public utilities over private land or along public roads for facilities such as electricity and water may need to be protected, infrastructures need to be maintained and/or improved, restrictions may be necessary where misuses occur, etc. The cadastre should therefore be seen as an integral part of the land management system (Dale, 1995).

The use of the land is closely related to land rights, which may be associated with certain limitations or constraints. In addition, the period over which certain land rights are held is important. An owner that has land rights for a long period may be more inclined to make investments than one who has land rights for a very restricted period. Access to land and ownership may thus impede or restrict the use of the land. Land rights constitute a condition under which land use develops. Land rights may restrict the choice of the various options of land use and it is, therefore, an important determinant of what type of actual uses may be found in a particular place and time. The type of land rights and who is holding these land rights (e.g., individual, family or private company) are recorded in the cadastral system.

5.2 Land-cover polygon

Land use describes the use of the object "land" and thus needs to be tied to a methodology in which the object is defined. This has led to the common practice to combine land use with land cover in the same class set, thereby attaching use to what you see because of what people do on the surface of the Earth.

However, land use has many aspects that go beyond land cover (e.g., socio-economics, legal aspects). Therefore, too much emphasis on land cover embodies the risk not to capture several aspects of land use.

The advantages of using land-cover polygons as basic unit of measurement are that cover can be observed and that tools like remote sensing and geographic information systems can help in a first stratification of the land-cover-related uses. Consequently, a spatial relationship is established between land use and land cover. A problem arises where land-use delineations do not concur with land-cover polygons. Several uses may take place within one land cover (e.g., in a building), as well as one land use may be applied to various land-cover types (e.g., certain types of free grazing). In the cases where the boundaries concur, one can aggregate either the land uses or the land covers. However, a land use may be confined to part of a land cover or parts of several land-cover polygons. In such cases, a further analysis and delineation would be required in order to define the basic unit of measurement. In practice, most of the land has been designated a certain function that applies to the whole unit under consideration. The cases that a land cover with a specific function does not concur with the land use are rare (e.g., certain types of recreation or tourism) (Jansen and Di Gregorio, 2003 and 2004). A methodology for mapping land use based upon available land-cover polygons is described by Cihlar and Jansen (2001). One should note that the land-cover/land-use relationship may change with time, thus establishment of the relationship alone is not enough.

5.3 Statistical sample unit

Statistics are often based upon a selection of areas that are representative for a much larger area, the so-called statistical sample unit. In Table 1 for instance the TER-UTI class set uses an area of $9m^2$ distributed in a systematic manner over the country territory to do annual systematic observations. This methodology has also been applied in Bulgaria besides France. This provided, among other projects, the experience integrated into the Land Use/Cover Area Frame Statistical Survey (LUCAS) launched by EUROSTAT and the Directorate General of Agriculture. LUCAS is making observations using a systematic grid: on a regular grid of 18 by 18km, each grid element contains 12x30 rectangular primary sampling units covering 90ha. In addition, there are 10 secondary sampling units per primary sampling unit. The secondary sampling unit area is considered as being equal to $7m^2$ (a circle with a diameter of 3m). These sampling units are revisited on a regular basis in order to describe them anew and analyse any changes. In 2005, this methodology has been revised in a regular grid of 1 by 1km covering the entire EU providing the base sample. From this base sample, the LUCAS master sample is extracted corresponding to a regular grid of 2 by 2km (e.g., 1 million points) where each point is photo-interpreted in order to stratify the sample in seven generic strata. From the stratified master sample, a sub-sample will be extracted for classification by field visit according to the full LUCAS class set (pers. comm. C. Duhamel, Landsis g.e.i.e).

6. Data quality

Harmonisation of class sets requires the analysis of data quality because correspondence between two class sets having two very different qualities may not be meaningful. In the metadata of each class set, parameters should be described related to the *positional and thematic accuracy*. The positional accuracy when using remote sensing can be divided into:

- Geo-referencing, i.e. the technical solutions for projecting the imagery onto the selected projection and spheroid aiming at providing for each pixel on the image its position on the ground by the means of a tern of coordinates.
- Location control, i.e. the correspondence between the coordinates of any arbitrary chosen point on the image and its position on the ground by the confrontation with better accuracy source data.
- Registration, i.e. the precision of the drawing/digitising system adopted defined as the difference between the same lines when interpretation is repeated of the same feature.

A statistically valid design for estimating accuracy parameters has three parts: (1) the response design specifies which data are to be collected at each sample location; (2) the sampling design specifies the locations at which the response data are to be acquired; and (3) the analysis lays out the formulas and tests to be applied to the observations (Boschetti et al., 2005).

One of the most common means of expressing thematic accuracy in remote sensing is the preparation of a classification *confusion matrix*, sometimes called *error matrix* or *contingency table*. The confusion matrix compares on a class-by-class basis, the relationship between known reference data, i.e. the ground truth, and the corresponding results of classification either in the form of pixels, cluster of pixels, polygons or groups of polygons (Lillesand and Kiefer, 2000).

Semantic harmonisation of class sets should consider the data quality aspect in a comprehensive manner and would need to address also the following two aspects that are still at the level of research (Jansen et al., 2005b):

- A quantitative measure should be provided of the harmonisation result of a class. In existing examples, the impression is often given that class correspondence is 100%, whereas more often than not the result will be much lower.
- A quantitative measure should be provided for the overall correspondence between two class sets similar to the overall accuracy calculated from the confusion matrix.

7. Example: land-use harmonisation in Albania

7.1 Use of a reference system and a data model

The land-use data harmonisation process is illustrated with an example form the EU Phare Land-Use Policy II (LUP II) project in Albania based upon the cadastral parcel as basic unit of measurement (Jansen, 2003; Jansen et al., 2006). The LUP II results are compared to the World Bank Albanian National Forest Inventory (ANFI) project based upon the land-cover polygon as basic unit of measurement and a class set defined with the FAO/UNEP Land Cover Classification System (Jansen et al., 2005a). The Albanian government needed an analysis of land-use change dynamics to better understand the past, monitor the current situation and to predict future trajectories in order to plan land uses and develop and implement appropriate policies. In the example data quality aspects have not been quantified as the basis for the harmonisation effort is the cadastre, where in the past land use has been systematically recorded, implying high data accuracy.

A standard hierarchical methodology for description of land use has been developed for Albania, as there is no such methodology available or an international land-use reference system. The developed Land-Use Information System of Albania (LUISA) adopts the function and activity parameters for systematic description and has been developed in complete synergy by the subject-matter specialist and information technology specialist.

Harmonisation between class sets can be achieved on the condition that the data structure of existing data sets is integrated in the newly developed class set. Here, problems may arise and if so they should be overcome. It may mean having to compromise and accommodate certain classes in a specific position in the class set that is neither the most suitable when considering the concepts adopted nor enhancing the class set’s internal consistency. Adoption of a hierarchical system will allow the applicability at various scales, from national, regional, to local. In addition, the class set structure is linked to a data structure, so one should not only be familiar with the subject matter of land use and the principles of classification, but also with information technology concepts (e.g., relational databases or object oriented approaches). In the above discussion, it is assumed that a common set of attributes distinguishes the classes to be compared and that class differences are primarily due to differences in boundary conditions. In the case of land use, this is a reasonable assumption (Wyatt et al., 1997).

In the context of the LUP II project, four data sets covering the period 1991-2003 (e.g., under socialist government, before and after privatisation) are important:

1. Statistical data from the Institute of Statistics (INSTAT) comprising seven classes;
2. Cadastral data from the Immovable Property Registration System (IPRS Kartela) comprising 41 classes (spatially explicit data);
3. Commune data comprising 14 classes (spatially explicit data); and
4. LUISA data comprising 48 classes where the most detailed levels of the hierarchy were used for land-use data collection (spatially explicit data).

Correspondence between classes of the available class sets has been inferred from the explicit record of how each class relates to LUISA using the available definitions. Three class sets would lead to three comparisons to be made for each class, whereas four class sets would request six comparisons per class. It was therefore more efficient to use LUISA as reference system. During its development, LUISA has been systematically and thoroughly tested. For the purpose of the LUP II project the land-use categories have been limited to four that each are linked to a set of laws. Each of these categories branches out into different levels, each level having its own set of classes and use of parameters, definitions and guidelines (Figure 2).

Insert Figure 2.

A link that is often ignored at an early stage of classification comprises the structure of data resulting from classification in a geo-database. The *data model* developed for the LUP II project distinguishes *spatial features* (e.g., land-use and soils) from *linear features* (e.g., roads and channels). The latter two classes are however also related to land-use because roads form the transport network, whereas channels form the drainage and irrigation network. This division has important implications for the way in which roads and channels appear in LUISA. In the data model linear features have been split into several segments; for each road or channel segment data is collected that deal with their actual state and maintenance. The advantage of having such segment information is that the user of the data can identify, for example, if anywhere on a road used for transporting agricultural products to the nearby market there is a segment that is in such a bad state that a vehicle cannot pass. If the road would be a single feature in the database, such an analysis would be impossible. Another example can be given using channels. In many class sets, one will find the class "irrigated agriculture" where the parameter irrigation is applicable to the whole polygon. In practice, irrigation channels may function only in part due to their maintenance state but such a polygon would still carry the parameter irrigated. A much more flexible approach is to separate irrigation channels from the agricultural fields and to split the channels in segments. Such a distinction permits the user to identify those fields that are actually irrigated from those that cannot be irrigated due to segment information on the state of the irrigation channels. One will thus not find every single possibility of a class in LUISA because of the data model adopted. It is sufficient to record roads and channels as land *cover* because the segment information can be combined with these features at a later stage of the data integration process in order to define land use.

Once correspondence with LUISA was established for each class of the class sets, land-use change could be analysed using just LUISA. Using different class sets with several classes results in numerous land-use changes making a meaningful analysis difficult. LUISA does not only act as a reference system for harmonisation of land-use class sets, it also acts as a reference system for harmonisation of land-use change. The LUISA class structure, i.e. the data structure, is tailored in an efficient and logical manner in order to identify land-use change processes. In principle, *land-use modifications* occur within a land-use category and the degree of modification depends on the level of the class (e.g., at Level IV modification is small, at Level III medium and at Level II high) and *land-use conversion* occurs between land-use categories. The exceptions are the Non-agricultural land-use classes, where modifications occur within one group (e.g., within Urban uses, within Transport, within Utilities, etc.) and conversions between groups (e.g., from Unproductive to Urban uses, or from Water bodies & waterways to Extraction & mining). In the Agricultural, Forests and Pasture & Meadows land-use categories conversions occur between categories, whereas modifications occur within a single category within and between groups (e.g., within the Agricultural Land-uses modifications exist within Permanent Crop Cultivation or between Temporary Crop Cultivation and Permanent Crop Cultivation, etc.). For the interpretation of land-use change a piece of software was written, the Land-Use Change Analyses (LUCA), that groups the changes according to the land-use change processes modification and conversion as shown in Table 4.

Insert Table 4 and Figure 3.

The harmonisation process between the different class sets and for harmonisation of land-use change using LUISA as reference system is shown in Figure 3.

7.2 Results of correspondence between the class sets

Correspondence between the classes of the four systems is important when using existing data sets coming from different sources at different levels of detail and trying to integrate and harmonise them in a geo-database. A table of correspondence has been prepared (Table 5) that shows that correspondence is often of the type one-to-many or many-to-many, especially when classes used at national level (e.g., INSTAT) are correlated with classes used at more detailed levels (e.g., IPRS Kartela, Commune and LUISA). However, if one looks at the more detailed level of the cadastral parcel unit of the IPRS Kartela and LUISA class sets, the many-to-many relationships occur less frequently and one gets a better idea about the correlation of single classes (Table 6 and 7).

Insert Tables 5, 6 and 7.

Some classes of IPRS Kartela do not correspond with a class of LUISA because they either occur below ground (e.g., 130, 332) and have not been included, or do not address a land-use (e.g., 344). Other classes are of a more generic nature than the detail of the classes used in LUISA resulting in a one-to-many relationship (e.g., 108, 110 and 118) or vice versa (e.g., LUISA classes 91, 92 and 93 with various IPRS Kartela classes). Other classes are more closely related to a land *cover* than a land-*use* (e.g., 118, 119, 135 and 336) and the relation with land use is not always apparent.

LUISA classes 95, 113, 114, 122, 124 and 133 do not correspond with any IPRS Kartela class. More detail has been introduced in the description of Agricultural and Non-agricultural land-uses. Suitable agricultural lands are limited in Albania and it is regarded as important to know why they might not be utilised for production of agricultural goods and/or services in the current agricultural year or for longer periods. The LUISA classes distinguished in the Forests and Pastures and Meadows categories have been introduced to better distinguish their range of uses instead of focussing mainly on their different land-cover type.

7.3 Comparison with the ANFI remotely sensed land-cover/use data set

The World Bank financed Albanian National Forest Inventory (ANFI) project provided an analysis of spatially explicit land-cover/use change dynamics in the period 1991-2001 using the FAO/UNEP Land Cover Classification System for codification of classes, satellite remote sensing and field survey for data collection and elements of the object-oriented geo-database approach to handle changes as an evolution of land-cover/use objects, i.e. polygons, over time to facilitate change dynamics analysis (Jansen et al., 2005a). Land-cover/use changes are the results of many interacting processes and each of these operates over a range of scales in space and time (Verburg et al., 2003). The detailed LUISA land-use data can be compared to the coarser ANFI data (scale 1:2,500 and 1:100,000 respectively), as far as space and time considerations both data sets represent more or less the same period (1991-2003 and 1991-2001 respectively), but the analysis of each data set gives a somewhat different view on the change dynamics at detailed versus aggregated data levels. At aggregated data levels the local variability of spatially explicit land-cover/use changes may be obscured, whereas patterns can be shown that at more detailed data levels may remain invisible and vice versa (Veldkamp et al., 2001).

The LUISA data set permits analysis of changes at the level of the individual cadastral parcel unit, thereby highlighting changes at the level of the landowner and/or land user. The ANFI data set provides a national overview of the major change processes, such as deforestation, urbanisation and increased pasture, but cannot provide conclusive evidence on especially the use of agricultural land (Jansen et al., 2005a). The LUISA data set provides an insight into the non-use of low productivity areas in hilly terrain and the extensive forms of agriculture practised on prime agricultural land because of the lack of fertilizer use and the breakdown of irrigation systems (Jansen et al., 2006). These two spatially explicit data sets are therefore complementary when analysing change dynamics.

It is important to note that the use of remote sensing for land cover is a common approach. Interpretation of satellite images can provide a quick overview of the type and location of different land-cover types. Often land-use elements are inferred from land cover (e.g., detection of a field pattern results in the class “agriculture”). However, the above example clearly demonstrates that land use requires a different approach because it contains many aspects that go beyond land cover. Even with the use of the most detailed satellite images, such aspects will not be covered.

7.4 Correspondence with an international class set

Reference should also be made to internationally established class sets used to describe national level land-use/cover data. These systems are not immediately related to the work of the LUP II project, but the value of the project outputs will be enhanced if correspondence to especially EU wide operational systems is assured. This will facilitate accession of Albania into the EU and continuity in data collection routines.

Land use is of high importance in the definition and evaluation of common sectoral policies in the EU, e.g. on environment, agriculture, transport and the integration of those policies in a comprehensive assessment and planning of the territory. EUROSTAT, the Statistical Office of the European Communities, has the mission to provide the EU with high quality statistical information service. To support policy formulation EUROSTAT launched in co-operation with the Directorate General responsible for Agriculture in 2000 the Land-Use/Cover Area Frame Statistical Survey (LUCAS) project that has been applied in the period 2001-2005 and it will be applied in a revised form in 2006 in 23 EU Member States.

Overall objectives of this survey are (EUROSTAT, 2001):

1. Collection of harmonised data (i.e. unbiased estimates) at EU level of the main land-use and land-cover areas and changes.
2. Inclusion not only of the usual agricultural domain but also the aspects linked with environment, multi-functionality, landscape and sustainable development.
3. A common sampling base (e.g., sampling frame, class set and data management) that interested Member States can use to obtain representative data at national, but also regional, level by increase of the sampling rate while respecting the general LUCAS approach.
4. Evaluation of the strengths and weaknesses of a point area frame survey as one of the pillars of the future Agriculture Statistical System (area frame means that the observation units are territorial subdivisions instead of agricultural holdings as used in the Farm Structure Survey).

Insert Table 8 and 9.

The main LUCAS land-use categories (version 1.0) are shown in Table 8. Correspondence with LUISA is shown, although based upon a different basic unit of measurement, in Table 9 at the individual class level. Only the LUISA classes related to land tenure (e.g., 11, 12 and 13) do not correspond with a LUCAS category, which is logical as they are distinguished using a non-inherent land-use parameter (Jansen, 2003).

8. Discussion and conclusions

Land use has been defined and interpreted in many different ways depending on the sector. The multi-disciplinary nature of the subject has hampered the development of a standardised methodology for classification as well as harmonisation of land uses worldwide. Existing class sets have been reviewed in order to distil the key elements but there is a genuine lack of consistency in applied methodology and adherence to the principles of classification, and a variety of basic units of measurement are used. Evaluation of the main parameters used in the existing class sets leads to the conclusion that the combination of just two parameters may suffice: function together with activity. Function is centred on the purpose of land uses, whereas activity groups all land undergoing a certain process resulting in a certain type of product.

The example in Albania shows how the use of a reference system, based upon the function and activity parameters and using the cadastral parcel as basic unit of measurement, may facilitate harmonisation of class sets in parallel with the achievement of harmonisation of land-use change. This reference system can form the basis for future standardisation of land-use class sets in Albania. In addition, the use of synergies between classification and information technology concepts (e.g., data model and resulting geo-database structure) should be enhanced.

Comparison of the cadastral-parcel-based class set of Albania with a polygon-based class set at coarser resolution shows that different levels of detail are needed when analysing land-use change. Remote sensing is a useful tool for gaining a quick overview of land-cover related land uses but the potential for a detailed and in-depth knowledge of land use is limited as other aspects, such as socio-economics, institutional, cultural and legal factors, are not captured by remotely sensed based land cover. Therefore, remote sensing can make a valuable contribution but its limits should be clear and complementary approaches should be used. Understanding land-use change dynamics does not only help to identify vulnerable places, but also vulnerable (groups of) land users that on their own are incapable to respond in the face of environmental processes and problems.

The way forward for harmonisation of land-use class sets is to promote and fully develop a parametric approach to classification. Commonalities in existing approaches should be emphasized and a set of commonly used parameters should be identified. Lessons can be learnt from harmonisation attempts at local, regional and national levels that are equally valid for a globally applicable land-use classification. Furthermore, a quantitative measure should be defined to express the harmonisation result of a class and between class sets.

Acknowledgements

This paper was prepared for the 12th Center for Environmental Remote Sensing (CEReS) International Symposium on Remote Sensing entitled “Maximizing the use of satellite data for understanding the Earth environment”, held 13-14 December 2005, Chiba, Japan. The author would like to sincerely thank the organising committee.
In addition, Christophe Duhamel (Landsis g.e.i.e., Luxembourg) is thanked for his suggestions concerning LUCAS and Giancarlo Carrai (SVALTEC S.r.l., Florence) for his comments on an earlier draft.

References

Adamec, J., 1992. Land-use classification study. First draft. Internal working paper. FAO, Rome.

Anderson, J.R., Hardy, E.E., Roach, J.T., Witmer, R.E., 1976. A land-use and land-cover classification system for use with remote sensor data. Geological Survey Professional Paper No. 964. U.S. Government printing office, Washington, D.C.

APA, 1999. Land-based classification standard. Second draft. American Planning Association, Research Department. Chicago, US.

Baulies, X., Szejwach, G., 1998. LUCC Data requirements workshop – survey of needs, gaps and priorities on data for land-use/land-cover change research. Organised by IGBP/IHDP-LUCC and IGBP Data and Information Systems (DIS), 11-14 November 1997. LUCC Report Series No. 3, LUCC International Project Office, Barcelona.

Boschetti, L., Foody, G.M., Friedl, M.A., Hansen, M.C., Herold, M., Mayaux, P., Morisette, J.T., Stehman, S.V., Strahler, A.H., Woodcock, C.E., 2005. Global land-cover validation: recommendations for evaluation and accuracy assessment of global land-cover maps. EC Joint Research Centre, Ispra, Italy.

CEC, 1993. Nomenclature des activités de la communauté européenne (NACE). Première révision. Règlement 761/93 du Conseil. Commission of the European Communities, Brussels.

Cihlar, J., Jansen, L.J.M., 2001. From land cover to land use: a methodology for efficient land-use mapping over large areas. *The Professional Geographer* 53(2): 275-289.

Dale, P.F., 1995. Land reform, land registration and the cadastre – a comparative analysis between Bulgaria, Hungary and Rumania.

Di Gregorio, A., Jansen, L.J.M., 2000. Land-cover classification system (LCCS): classification concepts and user manual. FAO/UNEP/Cooperazione italiana, Rome. (with CDROM)

Dolman, A.J., Verhagen, A., Rovers, C.A. (Eds.), 2003. Global environmental change and land use. Kluwer Academic Publishers, Dordrecht.

Duhamel, C., 1998. First approximation for a land-use classification. CESD-Communautaire, Luxembourg. FAO commissioned study.

Dumanski, J., Pieri, C., 2000. Land quality indicators: research plan. *Agriculture, Ecosystems and Environment*, 81:93-102.

ECE-UN, 1989. Proposed ECE standard international classification of land use. Economic Commission for Europe of the United Nations, Geneva.

EUROSTAT, 1991. EUROSTAT spatial statistics. Task force internal report on land-use statistics, EUROSTAT, Luxembourg.

EUROSTAT, 2001. Land-use/cover area frame statistical survey (LUCAS). Version 1.0. Eurostat, Luxembourg.

FAO, 1976. A framework for land evaluation. Soils Bulletin 32. FAO, Rome.

FAO, 1984. Guidelines: land evaluation for rainfed agriculture. Soils Bulletin 52. FAO, Rome.

FAO, 1998. FAO Statistical databases (FAOSTAT). FAO, Rome.

Guttenberg, A.Z., 1959. A multiple land-use classification system. *Journal of the American Institute of Planners*, 25: 143-50.

Guttenberg, A.Z., 1965. New directions in land-use classification. American Society of Planning Officials. Chicago.

IGU, 1976. World land-use survey. Report of the Commission to the General Assembly of the International Geographic Union. *Geographica Helvetica* No. 1. Pp. 28.

ITC/FAO/WAU, 1996. The land-use database. A knowledge-based software program for structured storage and retrieval of user-defined land-use data sets. Draft version, January 1996.

Jansen, L.J.M., 2003. A standard methodology for land-use description and harmonisation of data sets. Technical report 2. EU Phare Land-Use Policy II project. AGROTEC S.p.A. Consortium, Rome. 81p.

Jansen, L.J.M., Carrai, G., Morandini, L., Cerutti, P.O., Spisni, A., 2005a. Analysis of the spatio-temporal and semantic aspects of land-cover/use change dynamics 1991-2001 in Albania at national and district levels. *Environmental Monitoring & Assessment*, in print.

Jansen, L.J.M., Carrai, G., Petri, M., 2006, Land-use change dynamics 1991-2003 at cadastral parcel level in Albania: an object-oriented geo-database approach. In: Koomen, E., Bakema, A., Stillwell, J., Scholten, H. (Eds.), 2006. Simulating land-use change. Springer Publishers. 300pp. (with CDROM)

Jansen, L.J.M., Di Gregorio, A., 1998. The problems with current land-cover classifications: development of a new approach. Land-cover and land-use information systems for European policy needs, Luxembourg, 21-23 January 1998. E.C. EUROSTAT Studies and Research, Edition 1999, Theme 5: 93-102.

Jansen, L.J.M., Di Gregorio, A., 2002. Parametric land-cover and land-use classifications as tools for environmental change detection. *Agriculture, Ecosystems & Environment* 91(1-3): 89-100.

Jansen, L.J.M., Di Gregorio, A., 2003. Land-use data collection using the "Land-cover Classification System" (LCCS): results from a case study in Kenya. *Land Use Policy* 20(2): 131-148.

Jansen, L.J.M., Di Gregorio, A., 2004. Obtaining land-use information from a remotely sensed land-cover map: results from a case study in Lebanon. *Int. Journal of Applied Earth Observation and Geoinformation* 5: 141-157.

Jansen, L.J.M., Groom, G.B., Carrai, G., 2005b. Semantic data harmonisation of land-cover class sets using the FAO/UNEP Land-cover Classification System - Translator Module (LCCS-TM). Submitted to *Int. Journal of Applied Earth Observation and Geoinformation*.

Kostrowicki, J., 1977. Agricultural typology concept and method. Agricultural Systems No. 2:33-45.

Kostrowicki, J., 1980. A hierarchy of world types of agriculture. In: N. Mohammed (Ed.), 1992. New dimensions in agricultural geography. Vol. I - Historical dimensions of agriculture. Pp. 163-203.

Kostrowicki, J., 1982. Types of agriculture map of Europe: concept, method, techniques. In: N. Mohammed (Ed.), 1992. New dimensions in agricultural geography. Vol. I - Historical dimensions of agriculture. Pp. 227-249.

Kostrowicki, J., 1983a. Land-use survey, agricultural typology and land-use systems: introductory remarks. Rural Systems, Vol. 1 No. 1.

Kostrowicki, J., 1983b. Land-use systems and their impact on environment. An attempt at a classification. Adv. Space Res. Vol. 2, No. 8:209-215.

Kostrowicki, J., 1984. Types of agriculture in Europe: a preliminary outline. Geographia Polonica 50:131-149.

Lambin, E.F., Rounsevell, M.D.A., Geist, H.J., 2000. Are agricultural land-use models able to predict changes in land-use intensity? *Agriculture, Ecosystems and Environment*, Vol. 82: 321-331.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skånes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp. T.A., Vogel, C., Xu, J., 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change*, Vol. 11: 261-269.

LANES, 1998. Development of a harmonized framework for multi-purpose land-cover/land-use information systems derived from earth observation data. Final report. Concerted Action of the European Commission, Research Programme on the Environment and Climate. CESD-Communautaire, Luxembourg.

Lillesand, T.M., Kiefer, R.W., 2000. Remote sensing and image interpretation. Fourth edition. John Wiley & Sons, New York.

Meyer, W.B., Turner, B.L. (Eds.), 1994. Changes in land use and land cover: a global perspective. Cambridge University Press, Cambridge, UK.

McConnell, W.J., Moran, E.F. (Eds.), 2001. Meeting in the middle: the challenge of meso-level integration. An international workshop on the harmonization of land-use and land-cover classification. LUCC Report Series No. 5. Anthropological Center for Training and Research on Global Environmental Change - Indiana University and LUCC International Project Office, Louvain-la-Neuve.

Mücher, C.A., Stomph, T.-J., Fresco, L.O., 1993. Proposal for a global land-use classification. Internal final report, February 1993. FAO/ITC/WAU, Wageningen.

Paludan, C.T., 1976. Land-use surveys based on remote sensing from high altitudes. In: IGU, 1976. World land-use survey. Report of the Commission to the General Assembly of the International Geographic Union. *Geographica Helvetica*, 1: 117-24.

Remmelzwaal, A., 1989. Classification of land and land use. First approach. Internal working paper. FAO, Rome.

Sokal, R., 1974. Classification: purposes, principles, progress, prospects. *Science*, Vol. 85 (4157): 1115-1123.

Turner, B.L., Skole, D., Sanderson, S., Fischer, G., Fresco, L.O., Leemans, R., 1995. Land-use and land-cover change science research plan. IGBP Global Change Report No.35/ Human Dimensions Programme Report No. 7. International Geosphere-Biosphere Programme/Human Dimensions of Environmental Change Programme, Stockholm/Geneva.

UNEP/FAO, 1994. Report on the UNEP/FAO expert meeting on harmonizing land-cover and land-use classifications. Geneva, 23-24 November 1993. GEMS report series No.25. Nairobi.

UN, 1989. International standard classification of all economic activities (ISIC). Third revision. United Nations Statistics Division, Statistical Classifications Section, New York.

UN, 1998. Central product classification (CPC). Version 1.0. United Nations Statistics Division, Statistical Classifications Section, New York.

Urban Renewal Administration, 1965. Standard land-use coding manual: a standard system for identifying and coding land-use activities (SLUCM). Urban Renewal Administration, Housing and Home Financing Agency, and Bureau of Public Roads, Department of Commerce. Washington D.C.

Veldkamp, A, Kok, K., De Koning, G.H.J., Verburg, P.H., Bergsma, A.R., 2001. The need for multi-scale approaches in spatial specific land-use change modelling. *Environmental Modelling and Assessment*, Vol. 6: 111-121.

Verburg, P.H., De Groot, W.T., Veldkamp, A., 2003. Methodology for multi-scale land-use change modelling - concepts and challenges. In: Dolman, A.J., Verhagen, A. and Rovers, C.A.(Eds.), 2003. Global environmental change and land use. Kluwer Academic Publishers, Dordrecht. pp. 17-51.

Walker, B., 1998. GCTE and LUCC – a natural and timely partnership. *LUCC Newsletter* 3. pp 3-4.

Walker, B., Steffen, W., Canadell, J., Ingram, J. (Eds.), 1997. The terrestrial biosphere and global change: implications for natural and managed ecosystems. Synthesis volume. IGBP Book Series 4. Cambridge University Press, Cambridge, UK.

Wyatt, B.K., Greatorex-Davies, J.N., Hill, M.O., Parr, T.W., Bunce, R.G.H., Fuller, R.M., 1993. Comparison of land-cover definitions. Countryside 1990 series, Vol. 3. Report prepared for the Department of the Environment by the Institute for Terrestrial Ecology (ITE). Natural Environment Research Council, UK. Pp. 131 (with diskette).

Wyatt, B.K., Billington, C., De Bie, K., De Leeuw, J., Greatorex-Davies, N., Luxmoore, R., 1997. Guidelines for land-use and land-cover description and classification. ITE/WCMC/ITC/UNEP/FAO Internal unpublished working document. ITE, Monkshood, UK.

Wyatt, B.K., Gerard, F.F., 2001. What's in a name? Approaches to the inter-comparison of land-use and land-cover classifications. In: Groom, G., Reed, T. (Eds.), 2001. Strategic landscape monitoring for the Nordic countries, TemaNord 2001:523. Nordic Council of Ministers, Copenhagen.

Figure 1. Analysis of land-use planning (adapted from Guttenberg, 1965)

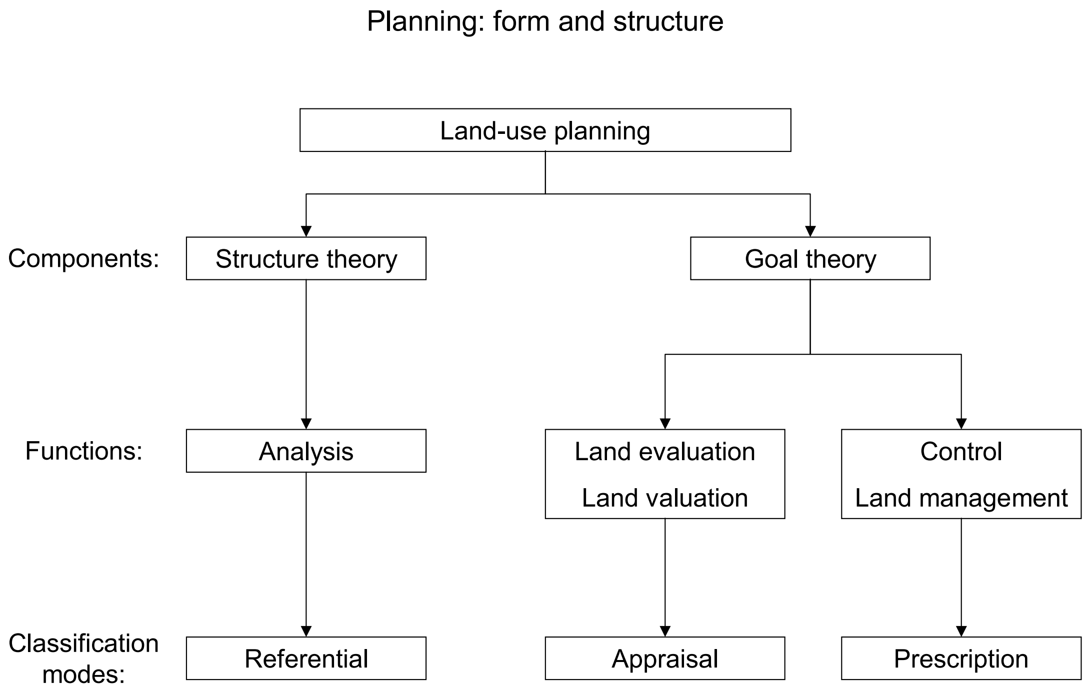

Figure 2. Overview of the LUISA class set with the four main categories Agricultural, Forests, Pasture & Meadows and Non-agricultural land uses (Jansen, 2003; Jansen et al., 2006)

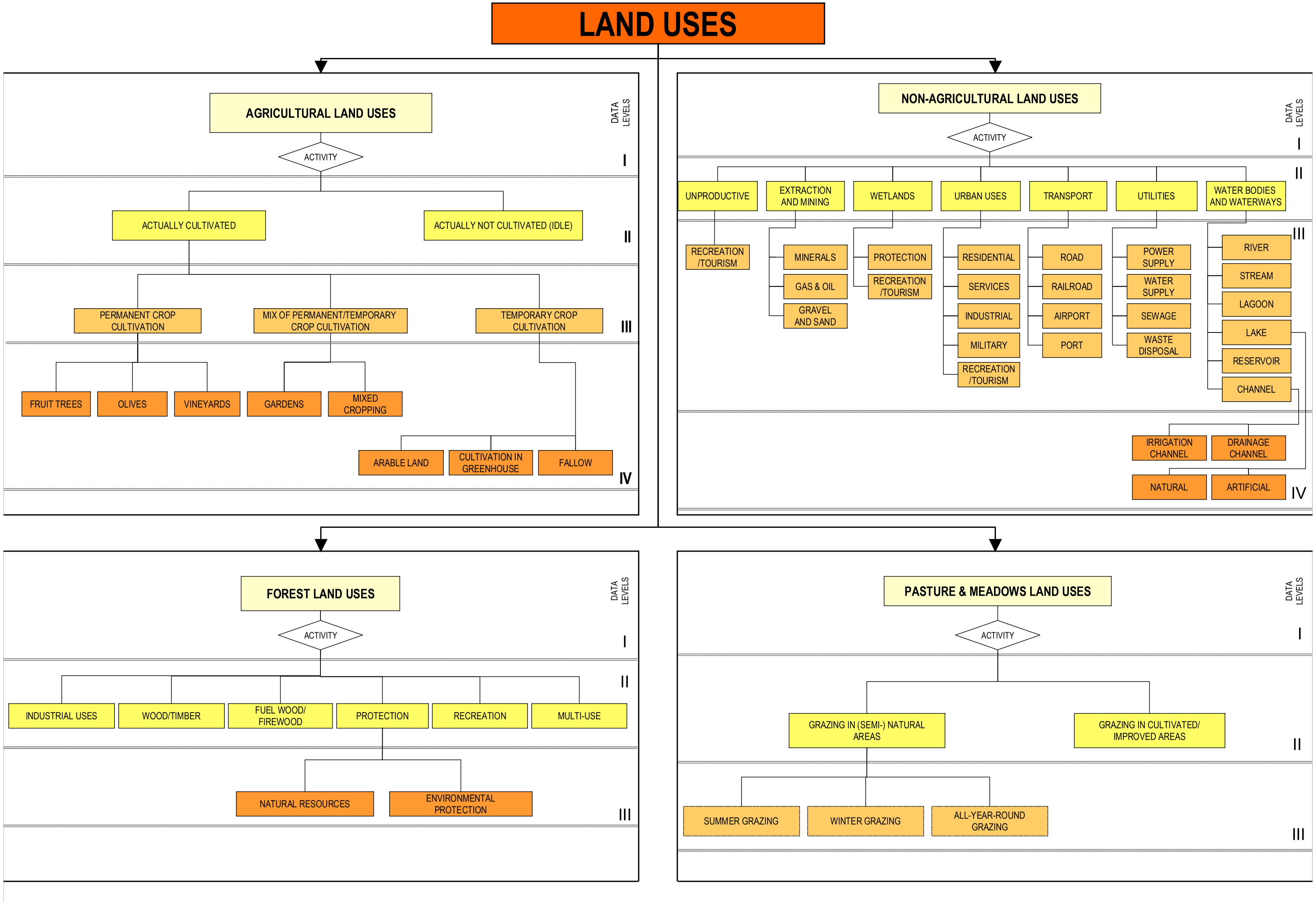

Figure 3. Harmonisation of class sets in Albania using a reference system (LUISA) and harmonising land-use change (LUCA)

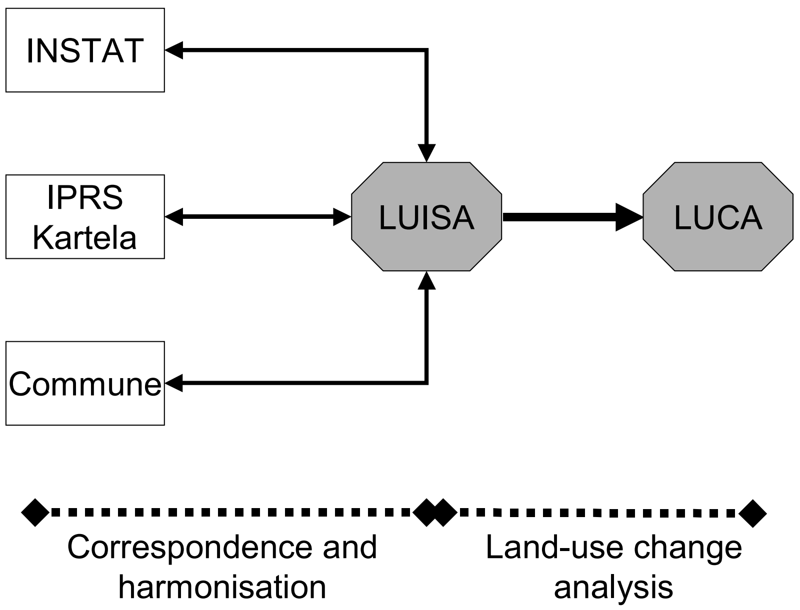

Table 1. Overview of adherence of selected systems to the general principles of classification (based upon Duhamel, 1998).

Land-use system / Principles	Anderson (1976)	ECE-UN (1989)	UK Land use (1972)	TER-UTI (1994)	Remmelzwaal (1989)	Adamec (1992)	Young (1993)	Mücher *et al.* (1993)
Completeness	only applicable to USA (as intended)	more applicable to northern European countries than Mediterranean	fulfilled	fulfilled	not fulfilled, too much geared towards agriculture	fulfilled	not fulfilled, some land uses are missing	fulfilled
Absence of overlap	absent	absent	fulfilled	fulfilled	potential confusion between mixed classes	absent	potential confusion between certain classes	fulfilled
Observation unit	not addressed	not addressed	spatial unit, hereditary and zone	a circle of $9m^2$	not addressed	not addressed	unit of management; population census unit	unit of biophysical management (e.g., plot)
Tool independent	remote sensing dependent	not addressed	independent	independent	not addressed	not addressed	not addressed	independent
Definitions and explanatory notes	no systematic reporting, definitions read like comments	definitions exist; unsystematic explanatory notes	non-existent	no definitions; explanations are given	no systematic definitions; no explanatory notes	non-existent	non-existent	non-existent
Interpretation rules	LC and LU are mixed	general usage of mixed classes; dominance is not defined	all uses are recorded, no weighing in mixed classes	hierarchy of uses requested but no rules exist to define	multiple uses are not discussed	non-existent	multiple uses are recognised: primary use refers to the value added to the holding	multiples uses exist; multiple sequences of operations are not dealt with
Inclusion of new objects	not mentioned, there is often an *Other* category	no systematic approach followed	possible	possible	not addressed	not addressed	not addressed	not addressed
Index of objects	non-existent	non-existent	existing	existing	non-existent	non-existent	non-existent	non-existent
Correspondence with other systems	non-existent	tentative correspondence with socio-economic systems	national Standard Industrial Classification (SIC)	table of correspondence with earlier versions	non-existent	non-existent	non-existent	non-existent

8 Table 2. Analysis of land-use characteristics used by several main class sets [1]

Main sector	Land-use characteristics			
	Function	Activity	Biophysical	Legal
Agriculture	x	x	x	
Fisheries	x	x	x	
Forestry	x	x	x	x
Economics	x	x		
Sociology	x	x		
Statistics	x	x	x	
Industry		x		x
Housing	x	x	x	x
Services		x		x

9

[1] Based upon: World Land-Use Survey (IGU, 1976), Anderson (Anderson *et al*., 1976), ISIC 3rd revision (UN, 1989), Standard International Classification of Land Use (ECE-UN, 1989), NACE 1st revision (CEC, 1993), Central Product Classification (UN, 1998), FAOSTAT (FAO, 1998), Land-Based Classification Standard (APA, 1999). For "forestry", use was also made of http://home/att.net/~gklund/DEFpaper.htm.

Table 3. The main categories of ISIC, 3rd revision (UN, 1998).

International Standard Industrial Classification of All Economic Activities		
Codes		Description of category
A	01	Agriculture, Hunting and Related Service Activities
	02	Forestry, Logging and Related Service Activities
B		Fisheries
C		Mining and Quarrying
D		Manufacturing
E		Electricity, Gas and Water Supply
F		Construction
G		Wholesale and Retail Trade
H		Hotels and Restaurants
I		Transport, Storage and Communication
J		Financial Intermediation
K		Real Estate, Renting and Business Activities
L		Public Administration and Defence
M		Education
N		Health and Social Work
O		Other Community, Social and Personal Service Activities
P		Private Households with Employed Persons
Q		Extra-Territorial Organizations and Bodies

Table 4. Grouping of the land-use changes according to LUCA (Jansen, 2003; Jansen et al., 2006)

Type of land-use change			Code
No change		Correspondence	1
Modifications	Low level	Low level modification in Agriculture	201
		Low level modification in Forests	202
		Low level modification in Pastures	203
		Low level modification in Non-Agriculture	204
	Medium level	Medium level modification in Agriculture	301
		Medium level modification in Forests	302
		Medium level modification in Pastures	303
		Medium level modification in Non-Agriculture	304
	High level	High level modification in Agriculture	401
		High level modification in Forests	402
		High level modification in Pastures	403
		High level modification in Non-Agriculture	404
Conversions		Agriculture-to-Forest	5
		Agriculture-to-Pasture	6
		Agriculture-to-Non Agriculture	7
		Forest-to-Pasture	8
		Forest-to- Agriculture	9
		Forest-to-Non Agriculture	10
		Pasture-to-Agriculture	11
		Pasture-to-Forest	12
		Pasture-to-Non Agriculture	13
		Non Agriculture-to-Agriculture	14
		Non Agriculture-to-Forest	15
		Non Agriculture-to-Pasture	16
Unknown		No correspondence [2]	99

[2] "No correspondence" means that the land-use change is unlikely to occur.

14 Table 5. Correspondence between land-use classes from different class sets at a generic level (Jansen, 2003)

Legal categories	Land-use classes		Class sets			
			INSTAT [3]	IPRS Kartela [4]	Commune [5]	LUISA [6]
Agriculture	Used agricultural area		b	-	1	1, 2, 3, 4, 5, 6, 7
		Area with arable land crops	c, d	101, 102	1a	6, 7
		Area with permanent crops	f	116, 125, 128, 131, 148	1b, 1c, 1d	1, 2, 3, 4, 5
	Non-utilised agricultural area		e	-	-	8, 9
Pastures and meadows		Grassland and pastures	g	108, 110, 153	2, 3a	51, 52, 53, 54, 55
Forests		Forests	h	118	3	31, 32, 33, 34, 35, 36, 37
Non-agricultural lands		Water bodies	-	107, 109, 111, 120, 138, 153	4a	131, 132, 133, 134, 135, 136, 137, 138
		Wetlands	-	336	-	81, 82
		Built-up areas	-	100, 103, 106, 114, 121, 129, 130, 136, 144, 152, 213, 261, 332, 337, 338, 339, 340, 341, 342	4b, 4c, 4d, 4e	91, 92, 93, 94, 95, 111, 112, 113, 114, 121, 122, 123, 124
		Barren	-	119, 135	4f	61
		Mining/extraction	-	117, 343	-	71, 72, 73

15

[3] a=Total Area (not represented in the table), b=Used agricultural area (UAA), c=Cultivated area with arable land crops, d=Main crops (the first ones), e=Non-utilised agricultural area, f=Area with permanent crops, g=Grassland and pasture, h=Forests.

[4] For explanation of the codes see Table 6. Classes 130, 332 and 344 not included.

[5] 1=Agriculture, 1a=Arable, 1b=Vineyards, 1c=Fruit trees, 1d=Olives, 2=Pastures, 3=Forest, 3a=Brush land, 4=Non-agricultural, 4a=Water body, 4b=Built-up, 4c=Cemetery, 4d=Roads, 4e=Railway, 4f=Barren.

[6] For explanation of the codes, see Table 7.

Table 6. Correspondence between land-use classes at the level of the cadastral parcel unit (Jansen, 2003)

IPRS Kartela land-use classes [7]		LUISA
Code	Class names	Class codes [8]
100	Apartment	91
101	Arable	6, 7, 8, 9
102	Arable + garden	6, 7, 8, 9
103	Water treatment facility	123
106	Building non-residential	92, 93, 94
107	Channel	137, 138
108	Pasture	51, 52, 53, 54, 55
109	Lake	134, 135
110	Meadows	51, 52, 53, 54, 55
111	River	131
114	Block of flats	91
116	Fruit trees	1
117	Oil well	72
118	Forest	31, 32, 33, 34, 35, 36, 37
119	Barren	61
120	Reservoir	136
121	Road	111
125	Garden (of private building)	4
128	Olives	2
129	Cemetery	92
130	Tunnel, underground	-
131	Vineyards	3
135	Rocky	61
136	Public area	92
138	Stream	132
144	Transformer building (step-up or step-down)	121
148	Fruit trees + garden	5
152	Railroad	112
153	Barrier (natural or artificial)	51, 52, 53, 54, 137, 138
213	Building for residential purpose	91
261	Sport field	92
332	Underground	-
336	Marsh	81, 82
337	Sidewalk	111
338	Unit (consisting of small shop or bar)	92
339	Garage	91
340	Studio	91
341	Power plant	121
342	Area associated to power plant	121
343	Mine area	71, 73
344	Transport equipment	-

[7] The IPRS Kartela classes do not have a hierarchical data structure, their structure is flat.
[8] For the explanation of the codes see Table 7.

18 Table 7. Correspondence between the land-use classes of LUISA and IPRS Kartela [9] (Jansen, 2003)

Category	LUISA Code	Description	IPRS Kartela Code
Agricultural land-uses	1	Fruit trees	116
	2	Olives	128
	3	Vineyards	131
	4	Gardens	125
	5	Mixed cropping	148
	6	Arable lands	101, 102
	7	Cultivation in greenhouse	101, 102
	8	Fallow lands	101, 102
	9	Actually not cultivated (idle and abandoned) lands	101, 102
Forests	31	Industrial forests uses	118
	32	Forests for wood/timber production	118
	33	Forests for fuel wood/firewood	118
	34	Protection of natural resources	118
	35	Forests for environmental protection	118
	36	Forests for recreation	118
	37	Multi-use forests	118
Pastures and Meadows	51	Grazing in (semi-) natural areas	108, 110, 153
	52	Summer grazing in (semi-) natural areas	108, 110, 153
	53	Winter grazing in (semi-) natural areas	108, 110, 153
	54	All-year-round grazing in (semi-) natural areas	108, 110, 153
	55	Grazing in cultivated/improved areas	108, 110
Non-agricultural land-uses	61	Recreation/tourism in unproductive areas	119, 135
	71	Mineral extraction and mining	343
	72	Gas and oil extraction	117
	73	Gravel and sand extraction/mining	343
	81	Protection of wetlands	336
	82	Recreation/tourism in wetlands	336
	91	Residential area	100, 114, 213, 339, 340
	92	Services	106, 129, 136, 261, 338
	93	Industrial area	106
	94	Military area	106
	95	Recreation/tourism in urban areas	-
	111	Road	121, 337
	112	Railroad	152
	113	Airport	-
	114	Port	-
	121	Power supply	144, 341, 342
	122	Water supply	-
	123	Sewage	103
	124	Waste disposal	-
	131	River	111
	132	Stream	138
	133	Lagoon	-
	134	Natural lake	109
	135	Artificial lake	109
	136	Water reservoir	120
	137	Irrigation channel	107, 153
	138	Drainage channel	107, 153

[9] For the hierarchical data structure of LUISA see Figure 2; for explanation of the IPRS Kartela codes see Table 6.

Table 8. LUCAS version 1.0 (EUROSTAT, 2001)

Land-Use/Cover Area Frame Statistical Survey	
Code	Land-use Category name
U11	Agriculture
U12	Forestry
U13	Fishing
U14	Mining – Quarrying
U21	Energy Production
U22	Industry – Manufacturing
U31	Transport, Communication, Storage, Protective Works
U32	Water, Waste Treatment
U33	Construction
U34	Commerce, Finance, Business
U35	Community services
U36	Recreation, Leisure, Sport
U37	Residential
U40	Unused

Table 9. Correspondence between the land-use classes of LUISA and LUCAS 1.0 (Jansen, 2003)

	LUISA [10]		LUCAS 1.0
Category	Code	Land-use category code	Code
Agricultural land-uses	1	Fruit trees	U11
	2	Olives	U11
	3	Vineyards	U11
	4	Gardens	U11
	5	Mixed cropping	U11
	6	Arable lands	U11
	7	Cultivation in greenhouse	U11
	8	Fallow lands	U11
	9	Actually not cultivated (idle and abandoned) lands	U11
Forests	31	Industrial forests uses	U12
	32	Forests for wood/timber production	U12
	33	Forests for fuel wood/firewood	U12
	34	Protection of natural resources	U12
	35	Forests for environmental protection	U12
	36	Forests for recreation	U12
	37	Multi-use forests	U12
Pastures and Meadows	51	Grazing in (semi-) natural areas	U11
	52	Summer grazing in (semi-) natural areas	U11
	53	Winter grazing in (semi-) natural areas	U11
	54	All-year-round grazing in (semi-) natural areas	U11
	55	Grazing in cultivated/improved areas	U11
Non-agricultural land-uses	61	Recreation/tourism in unproductive areas	U36
	71	Mineral extraction and mining	U14
	72	Gas and oil extraction	U14
	73	Gravel and sand extraction/mining	U14
	81	Protection of wetlands	?
	82	Recreation/tourism in wetlands	U36
	91	Residential area	U37
	92	Services	U34, U35, U36
	93	Industrial area	U22
	94	Military area	U35?
	95	Recreation/tourism in urban areas	U36
	111	Road	U31
	112	Railroad	U31
	113	Airport	U31
	114	Port	U31
	121	Power supply	U21
	122	Water supply	U32
	123	Sewage	U32
	124	Waste disposal	U32
	131	River	U13, U32
	132	Stream	U13, U32
	133	Lagoon	U13, U32
	134	Natural lake	U13, U32
	135	Artificial lake	U13, U32
	136	Water reservoir	U13, U32
	137	Irrigation channel	U32
	138	Drainage channel	U32

[10] For the hierarchical data structure of LUISA see Figure 2.