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Australian/New Zealand Standard™

Geographic information — Classification systems

Part 2: Land Cover Meta Language (LCML)

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Geographic information — Classification systems

Part 2: Land Cover Meta Language (LCML)

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee IT-004, Geographical Information/Geomatics, to supersede AS/NZS ISO 19144.2:2012.

The objective of this document is to specify a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different Land Cover classification systems to be described based on physiognomic aspects. This document recognizes that a number of Land Cover classification systems exist. It provides a common reference structure for the comparison and integration of data for any generic Land Cover classification system but does not intend to replace those classification systems.

This document is identical with, and has been reproduced from, ISO 19144-2:2023, *Geographic information — Classification systems — Part 2: Land Cover Meta Language (LCML)*.

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The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 287, *Geographic Information,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement), and in collaboration with the Food and Agriculture Organization of the United Nations (UN FAO).

This second edition cancels and replaces the first edition (ISO 19144-2:2012), which has been technically revised.

The main changes are as follows:

— This revision of ISO 19144-2:2012 has divided the original International Standard into additional parts.

— Material from ISO 19144-2:2012, Clause 9, on registration has been removed and is intended to be included in ISO 19144-4[1)].

— Material related to Land Use has been removed and is intended to be included in ISO/TS 19144-3[2)].

— The high-level model has been changed to promote the attribute of *cover* and *elementSpreadingGeometry* to the LC_Element level with the addition of the new attribute, *density*.

— Various changes have been made to certain types and classes (see Annex E).

1) Under preparation. Stage at the time of publication: ISO/PWI 19144-4:2023.

2) Under preparation. Stage at the time of publication: ISO/AWI TS 19144-3:2023.

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— Several of the definitions from ISO 19144-2:2012 have been improved in a backward compatible manner and UML and textual errors in the previous model have been corrected.

— A new Annex E has been added describing the changes to ISO 19144-2:2012 in more detail and addressing backward compatibility.

A list of all parts in the ISO 19144 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Efficient assessment of Land Cover and the ability to monitor change are fundamental to the sustainable management of natural resources, environmental protection, food security and successful humanitarian programmes. Such information is also required to help with raising levels of nutrition, improving agricultural productivity, enhancing the lives of rural populations and contributing to the sustainable growth of the world economy. However, in the past, policymakers and planners have not had access to reliable and comparable Land Cover data, both for lower-income countries and sometimes also at the regional and global levels.

Access has been limited by two factors: lack of mapping activities and lack of commonality between systems. The solution has been to carry out separate regional mapping projects using national or regional Land Cover classification systems. However, it has been difficult to compare or to exchange information between current systems.

The aim of this document is to enable the comparison of information from existing classification systems in a meaningful way without replacing them. The aim is to complement the development of future classification systems that can offer more reliable collection methods for particular national or regional purposes by allowing them to be described in a consistent manner.

A critical factor in implementing such global activities is the availability of an international standard for the documentation of Land Cover classification systems. This then provides a reliable basis for interaction without replacing the increasing number of national, regional and global Land Cover mapping and monitoring activities. This enables comparisons of Land Cover classes to be made regardless of mapping scale, Land Cover type, data collection method or geographic location.

Another critical factor is the availability of a common reference for Land Cover classification systems. This document provides a metalanguage expressed as a UML model that allows different Land Cover classification systems to be described.

This document establishes a metalanguage for a set of objects and rules (language) to describe Land Cover features based on physiognomy that can be part of different Land Cover Legends (nomenclature). This provides a framework for comparing different systems and nomenclatures such as CORINE, Africover, Anderson (USGS), Global Map and national systems, without replacing them. This is not a description of a nomenclature, nor is it a description of a specific set of classes.

An additional part of the ISO 19144 series (ISO/TS 19144-3[3)]) addresses Land Use aspects. Land Use by human activity is different from Land Cover. Land Cover is based on the physiognomic aspects of the plants and other elements covering the observed surface of the Earth. Land Use identifies the human activities, such as agriculture, mining or other actions taken by humans to modify the Earth cover. Land use is primarily defined in terms of human economic functions which result in a series of different human activities. In this context, Land Cover defines biophysical Earth objects on which human activities take place. The two types of classifications are closely related and in some Classification Systems they are sometimes mixed. The Land Use Metalanguage described in ISO 19144-3 can be used alone to simply describe Land Use, or it can be combined with the Land Cover Metalanguage to be able to describe classification systems that have mixed aspects of both Land Cover and Land Use.

Another part of the ISO 19144 series (ISO 19144-4[4)]) is intended to include a description of the registration and implementation aspects for Land Cover Land Use Classification. This allows code lists and other details used in the Land Cover and Land Use systems to be registered. Code lists allow attribute values and other characteristics to be open-ended and registration allows these elements to be defined.

EXAMPLE Soil types can make use of the UN FAO soil classification list of soil types,[45] or the more recent World Reference Base for Soil Resources,[59] or the USDA soil taxonomy[60] or the European Soils Bureau legend.[19]

3) Under preparation. Stage at the time of publication: ISO/AWI TS 19144-3:2023.

4) Under preparation. Stage at the time of publication: ISO/PWI 19144-4:2023.

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Appropriate references to externally managed lists or lists established particularly for the ISO 19144 series can be registered. In addition, whole classification systems described using the Land Cover or Land Use parts of the ISO 19144 series (i.e. this document and ISO 19144-3) can be registered.

This document is a joint International Standard with the UN Food and Agriculture Organization. Permission has been granted to ISO by the UN FAO to make a derived work based on any material developed or copyright UN FAO.

In this document UML attributes names are given in *italics*.

In accordance with the ISO/IEC Directives, Part 2, 2018, Rules for the structure and drafting of International Standards, in International Standards the decimal sign is a comma on the line. However, the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) at its meeting in 2003 passed unanimously the following resolution:

"The decimal marker shall be either a point on the line or a comma on the line."

In practice, the choice between these alternatives depends on customary use in the language concerned. In the technical areas of geodesy and geographic information it is customary for the decimal point always to be used, for all languages. That practice is used throughout this document.

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Geographic information — Classification systems

Part 2: Land Cover Meta Language (LCML)

1 Scope

This document specifies a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different Land Cover classification systems to be described based on physiognomic aspects. This document recognizes that a number of Land Cover classification systems exist. It provides a common reference structure for the comparison and integration of data for any generic Land Cover classification system, but does not intend to replace those classification systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19109, *Geographic information — Rules for application schema*

ISO 19103, *Geographic information — Conceptual schema language*

ISO 19123-1, *Geographic information — Schema for coverage geometry and functions Part 1: Fundamentals*

ISO 19144-1, *Geographic information — Classification systems — Part 1: Classification system structure*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19144-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

NOTE 1 The technical terms applying to plant physiognomy, and terms from other disciplines used to establish the classifiers in the classification system are not defined in this document.

NOTE 2 The term "class" is used in the ISO 19144 series to represent a construct in a classification system. However, the term has several meanings in other contexts, including in the UML modelling language. Where possible, attributes or other identifiers are needed to distinguish between the various use of the term "class".

3.1.1
abstract test suite
ATS
set of conformance classes that define tests for all requirements of a specification

Note 1 to entry: Evidence of conformance to all or part of a standard, awarded for passing one or more of the conformance test classes specified in that standard.

[SOURCE: ISO 19105:2022, 3.3]

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3.1.2
area of incidence
substratum area entirely topped by the entire Land Cover Meta Language (LCML) basic element itself or by its canopy effect

3.1.3
area of pertinence
area where a specific Land Cover Meta Language (LCML) element extends

3.1.4
characteristic
<classification> distinguishing qualitive attribute of a metalanguage basic element

3.1.5
class
<UML> description of a set of objects that share the same attributes, operations, methods, relationships, and semantics

[SOURCE: ISO 19103:2015, 4.7]

3.1.6
class
<classification> result of a classification process as part of a classification system which subdivides concepts within a given topic area

3.1.7
cover
<classification> area of incidence of a Land Cover Meta Language (LCML) basic element over the substratum in the area of pertinence of the basic element

3.1.8
element portioning
<classification> percent value of the area of pertinence of a single Land Cover Meta Language (LCML) basic element when two or more LCML basic elements are considered in the same stratum

Note 1 to entry: The sum of the whole portioning values for all elements considered within a stratum must always be equal to 100 %.

Note 2 to entry: Element portioning is distinct from strata portioning.

3.1.9
grid
<coverage> covering of a multi-dimensional region using quadrilateral shapes (in the 2D case) or their *n*-dimensional generation (in the *n*D case) with no overlaps and gaps

[SOURCE: ISO 19123-1:2023, 3.1.28, modified — Notes 1 and 2 have been removed.]

3.1.10
land cover
observed (bio)physical cover on the Earth's surface

Note 1 to entry: Land cover is distinct from land use.

[SOURCE: UN FAO, 2005, *LCCS — Land Cover Classification System — Classification concepts and user manual*][44]

3.1.11
land cover metalanguage
LCML
logical general model used to describe the characteristics of land cover features used as classifiers and the more specific rules that constitute a particular classification system

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3.1.12
land use
arrangements, activities and inputs people undertake in a certain land cover type to maintain it or produce change

EXAMPLE "Recreation area" is a land use term that can be applicable to different land cover types, e.g. sandy surfaces such as a beach; a built-up area such as a pleasure park; woodlands; etc.

Note 1 to entry: The definition of land use in this way establishes a direct link between land cover and the actions of people in their environment. Multiple land uses can coexist at the same location (e.g. forestry and recreation), contrary to land cover classes that are mutually exclusive.

[SOURCE: UN FAO. 2005, *LCCS — Land Cover Classification System — Classification concepts and user manual*][44]

3.1.13
point cloud
collection of data points in 3D space

[SOURCE: ISO/TS 19130-2:2014, 4.51]

3.1.14
physiognomy
<classification> general appearance of an object or terrain, without reference to its underlying or scientific characteristics

3.1.15
property
<classification> distinguishing additional physiognomic attribute of a metalanguage basic element

3.1.16
strata portioning
<classification > percent value expressing the portion by which a stratum comprises a part of the whole, where the aggregate of multiple related strata is constrained so that the sum of all of the related strata (projected in orthogonal plane) equals 100 %

Note 1 to entry: This allows the expression of situations where elements that are obscured by other elements cannot be seen, for example, the inability to see beneath the tree canopy in views from some types of satellite imagery.

Note 2 to entry: Strata portioning is distinct from element portioning.

3.1.17
triangulated irregular network
TIN
tessellation composed of triangles

[SOURCE: ISO 19123-1:2023, 3.1.50]

3.2 Abbreviated terms

CEC	Commission of the European Communities
CORINE	Coordination of Information on the Environment (EU)
LCCS	Land Cover Classification System
TDS	total dissolved solids
UML	unified modeling language

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UN FAO	United Nations Food and Agriculture Organization
UN FAO LCCS	UN FAO Land Cover Classification System
XML	Extensible Markup Language
XSD	XML Schema

4 Conformance

4.1 Conformance requirements and testing

Conformance to this document consists of alignment with the requirements established in 4.2, 4.3, 4.4, 9.2 and 9.3. The abstract test suite given in Annex A describes the applicable methodology for testing conformance to these requirements.

4.2 Conformance classes

Two conformance classes are identified in this document, one for the description of a Land Cover classification system and the other for the comparison between two or more Land Cover classification systems.

4.3 Conformance class 1 — Description of a Land Cover classification system

Requirement 1: The description of Legends or Land Cover Application Schema using this document shall consist of a set of UML classes with associated attributes that correspond to instantiations of the metalanguage classes described in Clause 8 or the extended metalanguage classes described through the mechanism described in Clause 9.

NOTE The levels of instantiation between the Land Cover Meta Language and a Land Cover Classification System and Application Schema and the relation to the ISO geographic information General Feature Model of ISO 19109 is described in Annex B.

4.4 Conformance class 2 — Comparison of Land Cover classification systems

Requirement 2: The process of comparison of two Land Cover classification systems shall be performed by developing descriptions of the two Land Cover classification systems, each in accordance with Requirement 1, and then identifying the differences on a class-by-class basis. This can be repeated for more than two Land Cover classification systems under comparison.

NOTE The level of detail of the comparison is dependent on the use case.

5 Notation

The conceptual schema specified in this document is described using Unified Modeling Language (UML), in accordance with ISO 19103.

Several model elements used in this schema are defined in other ISO geographic information standards, in particular ISO 19123-1 and ISO 19103. By convention within ISO/TC 211, names of UML classes, with the exception of basic data type classes, include a three-letter prefix that identifies the International Standard and the UML package in which the UML class is defined. UML classes defined in this document have the three-letter prefix of “LC_”. Examples in this document have the three-letter prefix “EL_”. The classes in the meta model in Annex B use the prefix “LM_”. Table 1 lists the other International Standards and packages in which UML classes used in this document have been defined.

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Table 1 — Sources of externally defined UML classes

Prefix	International Standard	Package
CL	ISO 19144-1	Classification system structure
CV	ISO 19123-1	Coverage geometry

The stereotype <<metalanguage>> is used throughout this document to identify metalanguage objects that compose the LC_LandCoverClassDescriptor. As illustrated in 8.5.1, LC_LandCoverClassDescriptor and its components are at a higher level of abstraction than the LC_LandCoverClass that form a Land Cover Classification System, which are at the Application Schema level. A Legend as described in ISO 19144-1 is the simplest type of Application Schema.

The stereotype <<metalanguage>> applies to a class whose instances are other classes that are described by the metalanguage class.

The term "class" is an English word with a dictionary definition. However, it also has several meanings within the ISO 19144 series, dependent upon context. Classification is a process and the results of a classification process is a “class”. The term "class" (<classification>; 3.1.6) is used in the ISO 19144 series to represent a construct in a classification system. However, the term "class" has several other meanings in other contexts. A classification system consists of a set of classes subdividing the concepts within a given topic area. There is an unavoidable conflict with the terminology when a modelling language such as UML is used to describe a classification system metalanguage such as the LCML. The UML modelling language uses the term "class" (<UML>; 3.1.5) as a construct in an object-oriented programming or data modelling paradigm, as the template for an object. That is, a UML class describes the properties associated with the instances of the class called objects. The term "class" is used in normal practice in both modelling and classification, and it is unreasonable for either modelling or classification to avoid the term. The term “Item Class” is also used in the process of registration, identifying the item that is registered. This term occurs in other parts of the ISO 19144 series. Adjectives have been used in this document where possible to reduce this confusion. For example, UML classes can be called “UML classes” and classification system classes can be called “classification classes” or “legend classes”. At times, a UML class describes a classification class and it is possible to dispense with the adjective since both meanings of "class" are equivalent in the context. The conflict results from the fact that there is a deep relationship between data modelling and classification as used in other domains.

There is a similar related potential conflict with the associated terms of "attribute" and "object". Adjectives have been used where possible, but at times it is necessary to derive the meaning from the context. Other terms where there is a potential for confusion are the terms “element”, “component”, “characteristic” and especially “attribute”. The use of these terms is potentially confusing as they have different meanings in different contexts. These terms come from different places and all that can be controlled is their usage in the ISO 19144 series. Care is taken to use adjectives with these terms to help to clarify their meaning.

6 Context

The purpose of this document is to define a common reference structure for the description and comparison of Legends or Application Schema for any generic Land Cover classification system. The approach has been to define an LCML expressed as a UML model that allows different Land Cover classification systems to be described. This approach provides a rigorous logical framework for the description of any Land Cover classification system. This will improve the harmonization and integration of spatial data sets defined using different Land Cover classifications and the Legends or nomenclatures developed from these systems and allow them to be compared and integrated.

This document defines an LCML for a Land Cover classification system. It recognizes that a number of Land Cover classification systems and nomenclatures exist in a number of countries and regions, and that these systems are well established and cannot be easily changed. In fact, portions of these systems are set in law in some nations with respect to Land Use legislation. The definition of wetland is of great importance in some nations because there is environmental legislation in many nations to protect

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wetlands. Yet the definition of wetland varies between jurisdictions, and there is a need to be able to compare this and other types of Land Cover object. A wide acceptance of an approach to handling the description of Land Cover depends upon its flexibility to accommodate nomenclatures derived from different systems.

NOTE The LCML is derived from the concepts in the Land Cover Classification System established by the Food and Agricultural Organization (FAO) of the United Nations (UN FAO LCCS version 3).[43],[44] The UN FAO LCCS classification system is one particular classification system for land cover based on plant physiognomy and does not exclude other classification systems being established for land cover for other purposes. The approach taken in this document is to avoid specific limitations such as fixed value ranges for attributes and the use of specific definitions for classifiers to increase the acceptability to the international community. The LCML defined in this document avoids complex definitions, prefixed ranges of values and specific detailed classification rules. It acts as a method to bring the Land Cover community together to create a common understanding of Land Cover nomenclatures with the aim of producing global, regional and national data sets able to be reconciled at different scales, levels of detail and geographic locations.

EXAMPLE One example of a Land Cover classification system is the UN FAO Land Cover Classification System.[43] The purpose of the UN FAO LCCS, which is standardized by the UN FAO, is to give to the international community one possible system for classifying Land Cover with a parametric approach that is compliant with the metamodel defined in this document. Other Land Cover classification systems can also be defined by other regional or national bodies. The UN FAO LCCS can be described as a set of classifiers and rules expressed in terms of the LCML. Any other national or multi-national Land Cover classification system can also be described in terms of the LCML. Examples of different national or regional classification systems are given in C.10 to C.15.

The LCML conforms to the general structure for classification systems defined in ISO 19144-1 in that a Land Cover classification system described in the LCML can be created so as to conform with ISO 19144-1. The structure used to represent the classified data can be that of a discrete coverage as described in ISO 19123-1. The classifiers described in accordance with the LCML can be maintained in a register, compliant with ISO 19144-4, i.e. the classes described using the metalanguage defined in this document can populate a register of classification systems. The register structure defined in ISO 19144-4 can also be used to define code lists and additional metalanguage elements that allow for extension of the LCML.

There are a number of code lists defined in this document that have been left empty. They can be filled by the use of registration as defined in ISO 19144-4. However, if they are not populated by registration then the reference to the code list can be considered as a character string attribute where a text string can be included.

The LCML provides a general framework of rules from which more exclusive conditions can be derived to create specific classification systems. It is a language based on physiognomy and stratification of both biotic and abiotic materials. The system can be used to specify any Land Cover feature anywhere in the world, using a set of independent diagnostic criteria that allow correlation with existing classifications and Legends.

Land Cover metalanguage descriptor objects are defined by a combination of a set of Land Cover metalanguage-elements. These Land Cover metalanguage-elements are divided into two categories:

a) basic metalanguage-elements, the elements that constitute the main physiognomic aspects of biotic and abiotic cover features, for example, for biotic features trees, shrubs, herbaceous vegetation;

b) metalanguage-element properties, that further define the physiognomic/structural aspect of the basic metalanguage-elements.

Further definition of the Land Cover classes can be achieved by adding the metalanguage-element characteristics. The characteristics are of two types: Land Cover element characteristics and Land Cover class characteristics. “LC_ClassCharacteristics” and “LC_ElementCharacteristics” are defined as optional descriptive elements not directly related to the physiognomic/structural characterization of the Land Cover metalanguage-element. “LC_ElementCharacteristics” can be applied to a single basic metalanguage-element. “LC_ClassCharacteristics” relate to a whole Land Cover class, defined as the combination of single or multiple strata of single or multiple basic metalanguage-elements. The definition of these characteristics in this document is informative, not normative, i.e. other sets

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of characteristics can be established and used with the LCML basic metalanguage-elements. These characteristics do not in any way prescribe how a Land Cover classification system is to be established. When used, they can assist in better defining a Land Cover class and therefore make it easier to compare classes between Land Cover classification systems.

The metalanguage generates mutually exclusive Land Cover classes, with specific rules for dealing with the functional elements of the language (basic metalanguage-elements and properties) and the different strata.

NOTE It is valid to apply the same characteristic to an element several times. For example, a shrub with two floristic aspects characteristics (each one with a single species name) and two sets of allometric measurements can be applied as two characteristics of a single element. This is allowed in the UML model.

All land covers can be accommodated in this highly flexible approach. The metalanguage can be used to describe different Land Cover classification systems in terms of the same basic metalanguage-elements, thus contributing towards data harmonization and standardization. Data defined using different nomenclatures can be used together with or fused with other data described according to a classification system which is also expressed in the metalanguage. By standardizing the principles and structure of a metalanguage, it is possible to interwork with other application areas or other nomenclatures within an application area. This is similar to interworking between other geographic information systems that conform to the same feature cataloguing methodology but use different feature catalogues, although in this case the concept of features are constrained to that of a classification system that partitions the attribute space (range) of a discrete coverage. Different nomenclatures, which are Legends of classes defined in accordance with the LCML system, can be used within multiple product specifications. Nomenclatures defined in accordance with the LCML conform to the general feature model defined in ISO 19109. This point is covered in more detail in Annex B.

7 Conceptual basis

7.1 Definition adopted for Land Cover

The common integrated approach adopted in this document defines Land Cover as the observed (bio) physical cover on the Earth's surface. Land cover is considered to be a geographically explicit feature that other disciplines can use as a geographical reference (e.g. for Land Use, climatic or ecological studies).

7.2 Geometric aspects of classification

A classification system subdivides any geographic area into smaller units that have a unique type. As identified in ISO 19144-1, the result is represented as a "discrete coverage". Coverages are defined in accordance with ISO 19123-1. One type of geometry used to represent a classification system is as a discrete coverage composed of a set of polygons. Each polygon would correspond to a coverage function element, discrete in its range and each such element would carry an attribute of type corresponding to a classification system class. When polygon geometry is used, each polygon geometry element would correspond to a single classification class type. This is by far the simplest and most common approach since each geometry element represents a pure (single concept) classification system element. However, there are other possible coverage geometries including point clouds, curves, grids and Triangular Irregular Networks (TINs). A grid or other tessellation of space can be used to define the coverage geometry elements. A discrete coverage element can contain a mixture of one or more classification system elements which need to be identified and distinguished. This approach is useful for geostatistics, but it makes the data difficult to use in other ways. It also has an advantage in describing change between one classified data set and another. Structures such as a "data-cube" can be used. In addition, continuous coverages can be used together with discrete coverages so that some continuously varying attributes can be carried in a data set in parallel with classified data. The use of alternate geometries including grids and continuous coverages can be used when comparing, integrating and fusing classified data from multiple sources. The metalanguage defined in this document addresses the meaning of independent Land Cover metalanguage-elements and not the geometry used to represent instances.

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7.3 Relationship to Land Use

Land Use addresses the "arrangements and activities that people undertake with respect to land". Land Use is defined with respect to different types of human activities that maintain or produce change to the land. There is a clear relationship between Land Cover and Land Use, in fact many existing older Land Use classifications are based on Land Cover information. However, the two are well separated concepts. Land Use is determined by the human activities over certain periods of time, while Land Cover is determined at one moment, including temporal aspects. This document addresses Land Cover. Aspects of Land Use and the relationship between Land Cover and Land Use are addressed in ISO/TS 19144-3.

7.4 LCML approach to class definition

7.4.1 LCML basic principle

A given Land Cover class in a Land Cover classification system is described by a Land Cover metalanguage object that has been formed by the combination of a set of pure (single concept) independent Land Cover metalanguage-elements. The unique combination of the metalanguage-elements describes the Land Cover class. Two Land Cover classes (from different Land Cover classification systems) can be compared by looking at the list of metalanguage-elements that are combined to describe each class.

Land cover metalanguage objects are pure in that they represent single concepts. These metalanguage objects can contain attributes, but these attributes are at the metalanguage level and are therefore templates for the description of attributes at the Legend or Application Schema level one or two levels of instantiation below the metalanguage. The metalanguage object attributes can also include data types, such as a Percentage Value type. These attributes are not a value itself, but rather a template for the description of an attribute at a lower level of instantiation.

7.4.2 Land cover classification system design criteria

Land cover classes are defined by a set of Land Cover metalanguage-elements as represented by the UML class LC_Element and its subtypes. Further definition of the Land Cover classes can be achieved by adding Land Cover metalanguage characteristics. "LC_ClassCharacteristic" and "LC_ElementCharacteristic" are defined as descriptive elements not directly related to the physiognomic/structural characterization of the Land Cover object.

Due to the heterogeneity of Land Cover metalanguage objects, certain design criteria have been applied.

All vegetated classes are derived from a consistent physiognomic structural conceptual approach that combines the basic metalanguage-elements for growth form with their physiognomic properties and arranges them in strata. At any level, specific characteristics can be added.

The non-vegetated metaclasses also use the same physiognomic approach related to the specular properties of the surface material.

The basic elements of each of the two Land Cover class groups constitute the main physiognomic aspects of biotic and abiotic cover features. For instance, for biotic classes (trees, shrubs, herbaceous vegetation etc.), the "properties" that further define the physiognomic/structural aspect of the basic objects are mainly the horizontal and vertical arrangement of the basic metalanguage-element cover and height. All of these elements (or part of them) can be arranged in one or more layers or strata.

Further definition of the Land Cover classes can be achieved by adding Land Cover characteristics. Land cover characteristics are defined as descriptive elements not directly related to the physiognomic/structural characterization of the class. Land cover element characteristics relate to the basic metalanguage-element itself. Land cover class characteristics relate to the whole final Land Cover metaclass, defined as the combination of single or multiple strata of single or multiple basic meta-elements.

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This results in a Land Cover class defined by specific rules that govern the place and the functional position of all elements of the language as basic metalanguage-elements and their properties, Land Cover characteristics and the different strata composition.

7.4.3 General rules for classification

The factors governing the concepts of classification of Vegetated and Non-Vegetated metaclass groups are:

— the definition of appearance or physiognomic aspect of the basic meta-elements LC_Vegetation and LC_AbioticSurface;

— the definition of the layering or strata of vegetated and/or abiotic metaelements.

The two main aspects are described in 7.4.4 to 7.4.5.

7.4.4 Land cover metalanguage-elements

The fundamental structure of LCML addresses the physiognomic/structural aspects of Land Cover. Physiognomy relates to the physical appearance of the elements. This is exemplified by the list of the basic elements (LC_Element) that are further characterized by specific attributes called properties. The structural aspect includes both the horizontal and the vertical disposition of the basic elements. The horizontal disposition of any basic elements (LC_Element) is described by the attribute cover, which is a property of the LC_Element. The vertical aspect is described by the use of the structural object "strata" (LC_Stratum). A horizontal pattern is a mechanism to describe a complex Land Cover object composed of two or more distinct Land Cover features together.

The description of each of the Land Cover metalanguage-elements, the subtypes of LC_Element, is given in the glossary of Land Cover elements in Annex D. This description is informative in that it provides meaning to the subtypes of LC_Element, but it does not in any way provide definitions for classes in a particular Land Cover classification system. The relationship between each of the Land Cover metalanguage-elements is given in the UML model in Clause 8. These are arranged by physiognomic aspect. The model also shows how the Land Cover elements can be combined to form strata and how these can be combined to form Land Cover metaclasses.

7.4.5 Layering

Several vegetated or abiotic (non-vegetated) basic metalanguage-elements can be combined to form a layer or stratum and these strata can be combined to form a metalanguage descriptor object. There is no limit to the number of strata and to the number of metalanguage-elements (vegetated and/or abiotic) forming the strata. One or more layers can be further characterized by their temporal or vertical relationship.

7.4.6 Packages

The UML model of each of the Land Cover metalanguage-elements is given in Clause 8. The metalanguage objects are organized into several packages. The package LC_LandCoverClassStructure describes the high-level structure of the model. The packages LC_Vegetation and LC_Abiotic define the basic LC_Element metalanguage objects for vegetation and non-vegetation (abiotic) surfaces. The optional characteristics at the UML class level and at the element level given in LC_ClassCharacteristics and LC_ElementCharacteristics further refine the metalanguage objects. The metalanguage value types given in LC_ValueObjectTypes define the allowable basic numerical types with constraints. These value objects represent templates for the description of attributes with specific data types at lower levels of instantiation and do not take on values at the metalanguage level. This is represented in Figure 1.

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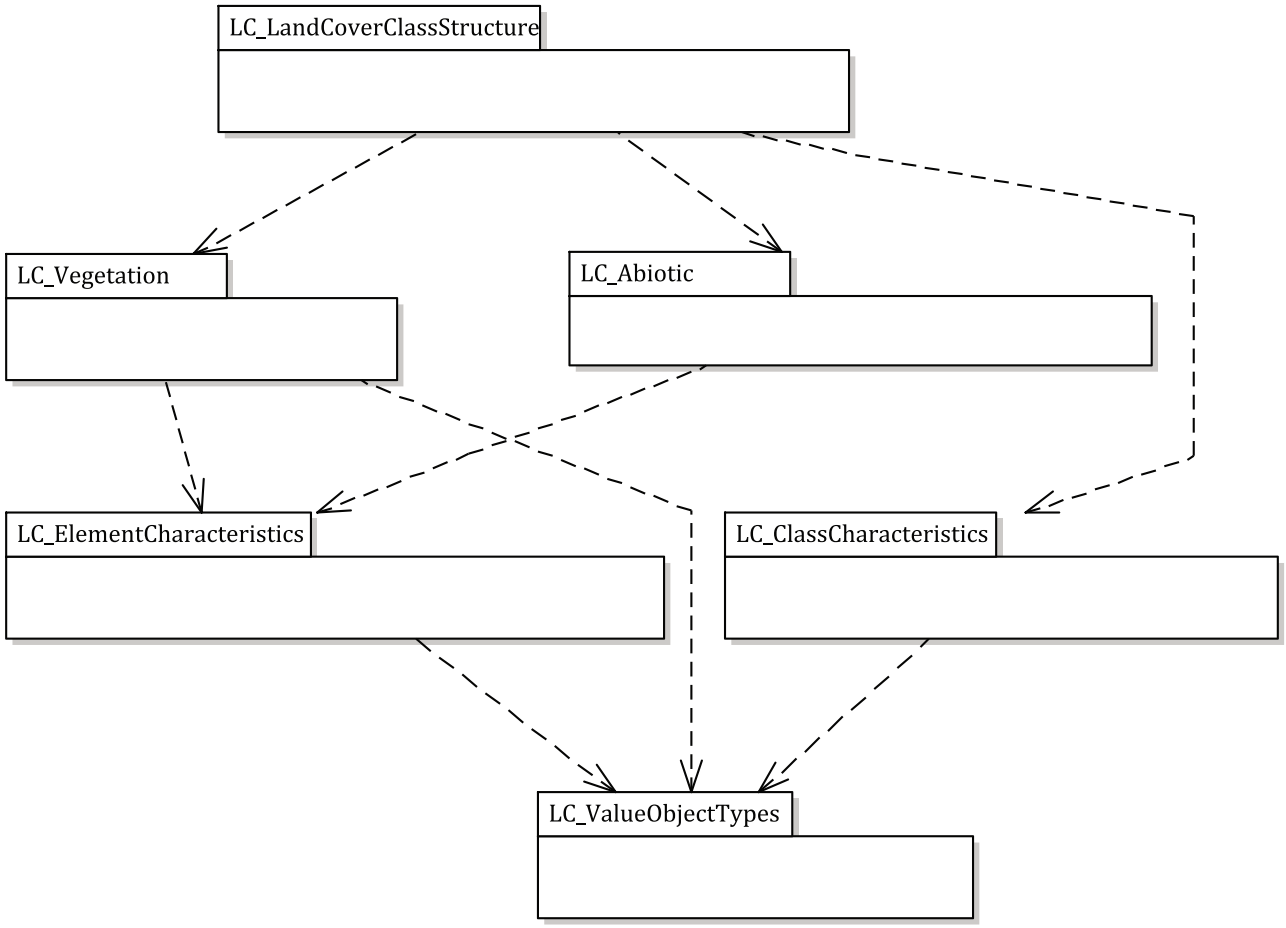

Figure 1 — LCML packages

8 LCML objects

8.1 Overview of LCML objects

The LCML is a metalanguage which can be used to describe a wide variety of Land Cover classification systems. The LCML operates by describing each Land Cover class in a Land Cover classification system in terms of a set of basic elements that, when combined, describe each aspect of the Land Cover classification system class. That is, each Land Cover class in a Land Cover classification system can be modelled using the basic element objects defined in the LCML. These elements are all subtypes of the object LC_Element, so any particular Land Cover classification system class can be described as a combination of a set of LC_Element subtype A + B + Q + Y, etc. Two different Land Cover classification system classes (from different Land Cover classification systems) can be compared by examining the LC_Element subtypes of which it is composed. If one classification class from one system is composed of LC_Element subtype A + B + Q and another of LC_Element subtype A + B + Y then it can be determined that the difference is the "Q" element. Being able to compare Land Cover classification systems in this detailed manner is important for establishing mappings so that data sets can be generated by the fusion of data from different sources.

The LCML described in this document is one of many possible metalanguages. Any set of basic elements that fully describe a topic area could be chosen as the basic vocabulary to establish a metalanguage. It is possible to establish other metalanguages based on different criteria. However, in order to perform a comparison and to integrate data from different Land Cover systems, it is necessary to standardize one metalanguage. This avoids the need to standardize classification systems.

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8.2 Relation to ISO 19144-1

The LCML metalanguage is used to describe a Land Cover classification system which is itself a UML model of classes that is then used to generate a Legend (or nomenclature).

A classification system consists of a set of Land Cover Classes that are established to exhaustively represent a particular aspect of the reality. The totality or a subset of these classes can be selected to describe a particular geographic area establishing a Legend or nomenclature. A Land Cover classification system is general in that its classes do not address a specific geographic area or collection scale, whereas a Legend or nomenclature is established specifically for a geographic area. The relationship between a classification system and Legend is described in ISO 19144-1. There are two separate semantic levels of abstraction involved. A Legend (or nomenclature) is concrete in that it defines Legend classes, instances of which can exist within a particular geographic area. A classification system is a semantic level of abstraction above a Legend that characterizes the functional relationship of a set (finite or infinite) of possible classes and defines their descriptive criteria. The LCML metalanguage is another semantic level of abstraction higher with respect to a classification system. The metalanguage provides the structure so that a classification system can be described.

The initial (root) UML class of the LCML model is the LC_LandCoverClassificationSystemMetaLanguage object. This object is composed of all the Land Cover elements used to describe the classes that make up a classification system as given by LC_LandCoverClassificationSystem. LC_LandCoverClassificationSystemMetaLanguage object is an aggregation of the Land Cover descriptor objects, LC_LandCoverClassDescriptor. The LC_LandCoverClassDescriptor object describes the LC_LandCoverClass, which is a subtype of CL_LegendClass as defined in ISO 19144-1. The LC_LandCoverClassDescriptor object is the link to the more general classification system structure in ISO 19144-1. An Application Schema for a Land Cover classification system described in conformance with this document and established in conformance with ISO 19109 includes the classification system structures defined in ISO 19144-1.

8.3 Composition of a LC_LandCover object

The LC_LandCover objects are composed of classification system elements, LC_Element. These elements can be organized into strata (or layers) through the LC_Stratum object. Specific rules apply to the composition of a stratum and the relationship of elements in different stratum. The LC_Elements in a stratum can also be organized so as to describe a horizontal pattern through the UML class LC_HorizontalPattern.

The LC_Element metalanguage object is an abstract UML class that is a generalization of a large number of subtypes. These subtypes form the basic elements of the LCML metalanguage model. A classification system, described in terms of the metalanguage, consists of Land Cover classes formed as instantiations of the LCML metalanguage model sub-elements in various combinations.

The structure of the LCML is represented in UML. The definitions of each of the Land Cover basic element classes, the subtypes of LC_Element, are contained in an associated glossary. The glossary is informative in that it is used as a guide for matching classes in a Land Cover classification system with a set of descriptive elements from the metalanguage, but it does not dictate the definitions of the classes in any Land Cover classification system. The definitions and their inheritance and other relationships are also contained in a register. This makes the LCML extensible since additional basic elements can be defined as required. Registration is described in ISO 19144-4.

8.4 Elements of the LCML metamodel

The schema specified in Clause 8 describes the structure of the LCML. The schema consists of the elements defined in 8.5 to 8.28. The schema is specified in UML 2.0 in accordance with ISO 19103.

NOTE The UML model makes use of constructs available in UML 2.0. In particular, the elements of the metalanguage are described using the <<metalanguage>> stereotype which is a particular type of interface at a higher level of instantiation. The Land Cover Classification System elements conform to the metalanguage interface that the Land Cover Meta Language model element establishes.

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8.5 High level structure

8.5.1 High level structure subtypes

The high-level structure of the LCML consists of the relationships between the LC_LandCoverClassificationSystemMetaLanguage object and the aggregation of a set of LC_LandCoverClassDescriptor objects. The LC_LandCoverClassificationSystemMetaLanguage object is a description of a Land Cover classification system as represented by the UML class LC_LandCoverClassificationSystem. The individual LC_LandCoverClassDescriptor objects can be serialized to produce LC_LandCoverClass(s) which correspond to individual classes in a Land Cover classification system. LC_LandCoverClass is a subtype of CL_LegendClass as defined in ISO 19144-1. This is represented in Figure 2.

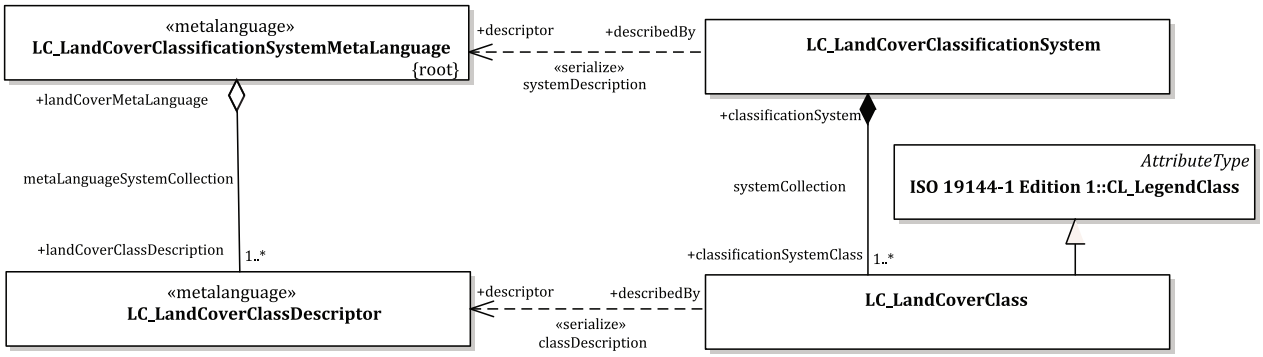

Figure 2 — High level structure of the Land Cover Classification model

8.5.2 High level structure classes

8.5.2.1 LC_LandCoverClassificationSystemMetaLanguage

The LC_LandCoverClassificationSystemMetaLanguage object is composed of all the Land Cover elements that, when serialized, describe the classes that make up a classification system as given by LC_LandCoverClassificationSystem.

The LC_LandCoverClassificationSystemMetaLanguage object has one relationship, *MetaLanguageSystemCollection*. LC_LandCoverClassificationSystemMetaLanguage is an aggregation of the Land Cover objects, LC_LandCoverClassDescriptor.

The diagram in Figure 2 shows that there is a parallel relationship between the descriptors that compose the metalanguage and the Land Cover classes that compose a Land Cover classification system. The descriptors are used to describe each classification class in a Land Cover classification system, and the whole metalanguage is used to describe the whole classification system. The LC_LandCoverClass is a subtype of the more general CL_LegendClass described in ISO 19144-1.

8.5.2.2 LC_LandCoverClassificationSystem

The LC_LandCoverClassificationSystem object is described by the components of the LC_LandCoverClassificationSystemMetaLanguage object. It corresponds to a Land Cover classification system. It consists of all the Land Cover classes in a Land Cover classification system.

This object has the relationship *systemCollection*. It is an aggregation of LC_LandCoverClass objects. It is also related to LC_LandCoverClassificationSystemMetaLanguage by the dependency relation that indicates a LC_LandCoverClassificationSystem described by the serialization of the metalanguage objects that compose the LC_LandCoverClassificationSystemMetaLanguage.

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8.5.2.3 LC_LandCoverClassDescriptor

The LC_LandCoverClassDescriptor object is the metalanguage level abstraction for a Land Cover class in a Land Cover classification system. The LC_LandCoverClassDescriptor object is used to describe the LC_LandCoverClass.

This UML class is an element in the aggregation in the *metaLanguageSystemCollection* relationship with the LC_LandCoverClassificationSystemMetaLanguage object. It is also related to LC_LandCover by the dependency relation which indicates that the LC_LandCoverClass is described by the serialization of the metalanguage objects that compose the LC_LandClassCoverDescriptor.

8.5.2.4 LC_LandCoverClass

The LC_LandCoverClass metalanguage object is the result of the serialization of the LC_LandCover object, i.e. it is related to LC_LandCoverClassDescriptor by a dependency relationship that indicates that the LC_LandCoverClass is described by the serialization of the metalanguage objects that compose the LC_LandCoverClassDescriptor. It corresponds to a single Land Cover class in a Land Cover classification system.

This object has a relationship *systemCollection* with the object LC_LandCoverClassificationSystem.

This object is a subtype of the UML class CL_LegendClass as defined in ISO 19144-1; that is, it is a specialization of a general classification system CL_LegendClass for the use of Land Cover.

8.6 Land Cover Meta Language object structure

8.6.1 Land Cover Meta Language object structure subtypes

The meta language object structure establishes the rules for the aggregation of occurrences of LC_Element, into the object LC_LandCoverClassDescriptor, that when realized produces a classification class in a Land Cover classification system or Application Schema at a lower level of instantiation than the metalanguage. Occurrences of LC_Element can be combined in layers using the *multiStrataComposition* relationship between LC_Element and LC_Stratum. The relationship of the LC_Elements within a layer is given by the *sequentialTemporalRelationship*. Several types of relationships can be described by the LC_ElementRelationInSameStratum association class. There can be any number of strata. The relationship between the strata is given by the *interStrataRelationship*. Several types of relationships including a *conditional* relationship and an *onTop* relationship can be described. Elements in a stratum can be built upon the same baseline or they can be indicated to be on top of another stratum. This allows the description of the vertical relation between strata. The default value for the LC_OnTopType is baseline. The *multiStrataComposition* relationship allows for the construction of horizontal patterns. The relation class LC_PlanarStrataComposition provides the attribute *strataPortioning* which expresses the portion by which the stratum comprises a part of the whole. This is represented in Figure 3.

The code lists that support the following Land Cover Meta Language object structures are described in Figure 4:

LC_ElementHorizontalSpreadingType,

LC_ElementPresenceType,

LC_StratumPresenceType,

LC_SequentialTemporalRelationshipType, and

LC_OnTopType.

These code lists may be extended through registration. For the LC_OnTopType code list, other relations (e.g. previousE4, previousE2-5, stratum3E4, etc.) which are logical extensions of the predefined relations in the enumerated value list in LC_OnTopType can be defined through registration. However,

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these are not predefined in this document for reasons of simplicity and because such complex relations would be used infrequently.

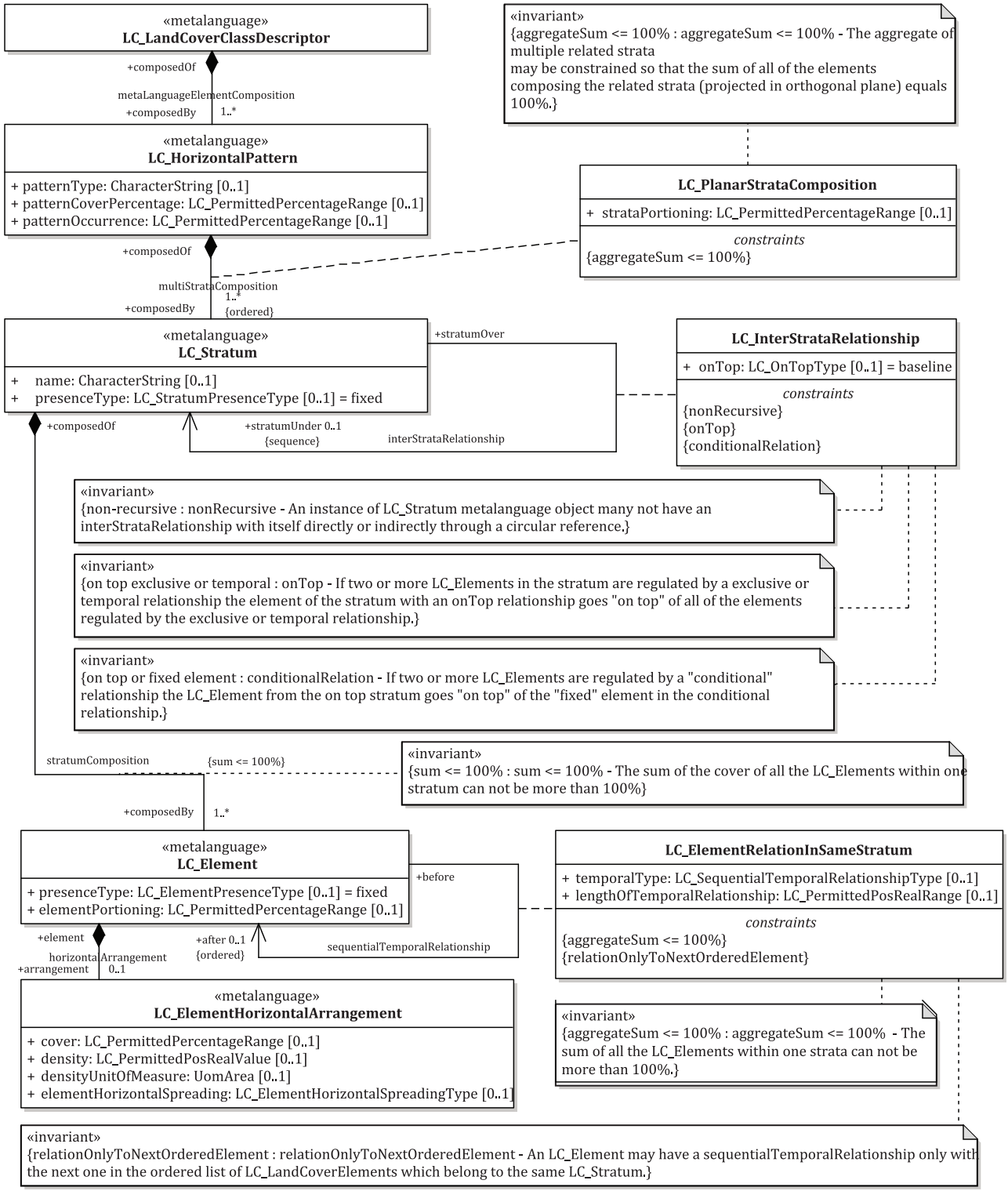

Figure 3 — Land Cover Meta Language object structure

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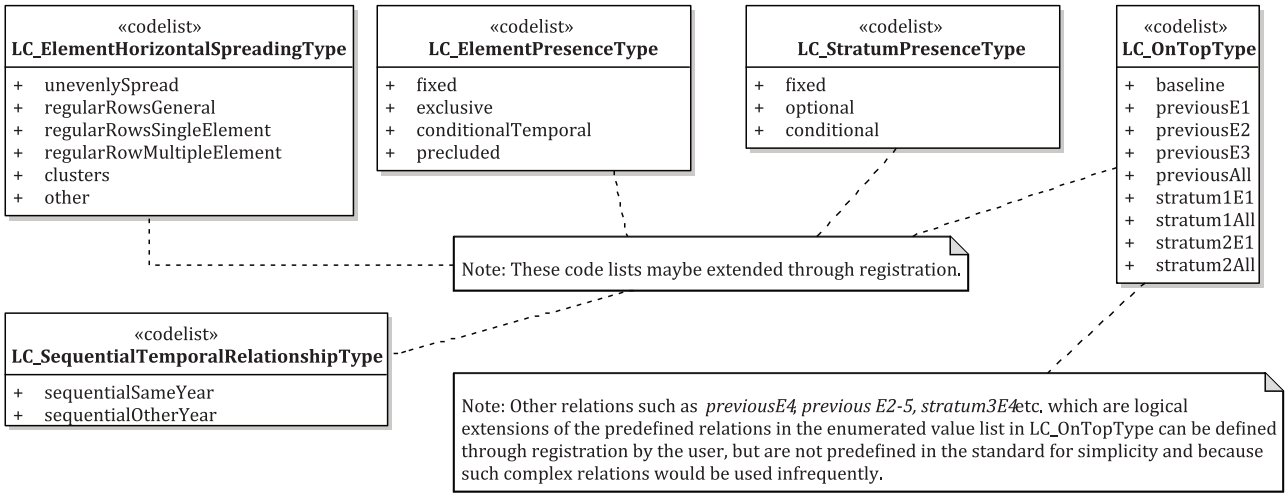

Figure 4 — Code lists that support the Land Cover Meta Language object structure

8.6.2 Land Cover Meta Language object structure classes

8.6.2.1 LC_LandCoverClassDescriptor

The Land Cover Meta Language object structure establishes the rules for the aggregation of occurrences of LC_Element, into the object LC_LandCoverClassDescriptor. An LC_LandCoverClassDescriptor object is composed of classification system elements LC_Element. These elements can be organized into stratum (or layers) through the LC_Stratum object. Specific rules apply to the composition of a stratum and the relationship of elements in different stratum. The LC_Elements in a stratum can also be organized so as to describe a horizontal pattern through LC_HorizontalPattern. Annex F provides additional explanation of the vertical and horizontal characterization of Land Cover features.

This object has a composition relationship with the object LC_HorizontalPattern through the relation metaLanguageElementComposition.

NOTE The "aggregation" referred to in this subclause is a UML strong aggregation (composition) which is a combination of the occurrences of the constituent elements.

8.6.2.2 LC_HorizontalPattern

The LC_HorizontalPattern object allows the ordering of LC_Stratum objects, consisting of single or groupings of LC_Elements, into one or more horizontal pattern(s). The horizontal pattern can be used when a complex description of particular Land Cover features is needed.

For instance, this is the case when a land feature is composed by two or more distinct Land Cover aspects that is handled or percived as a “unicum” independently from scale constraints.

NOTE 1 The term “unicum” in this context designates a heterogeneous set of Land Cover elements represented as a single unit. This is used where the given Land Cover type makes sense only if the distinct Land Cover features are treated together. For example, "polders" in the Netherlands or "dehesas" in Spain and "montado" in Portugal. The main component in both cases, is the grass, but this grass will not exist if the dykes on the former or the trees in the later case are not present/accounted for.

An additional use is the detailed descripation of the vertical/horizontal relationship of the basic elements constituting a specific Land Cover feature.

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The LC_HorizontalPattern object permits the expression of relationships such as “grass under trees” by developing horizontal patterns that include the composition of two or more strata that have a vertical relationship.[15][35] This vertical relationship can be described by the relation *interStrataRelationship*.

NOTE 2 This structure is based on the tegon concept developed by the Joint Research Centre of the European Commission and used in applications, such as the European Union Common Agricultural Policy.

An example is shown in Figure 5 and Figure 6 where there are two strata, one containing trees and one containing grass. The strata representing grass can be organized into two portions, one representing grass under trees and the other grass that is not under the trees. The description of vertical relationship is important for applications such as agricultural crop monitoring.

In Figure 5 each stratum is independent from each other, therefore the cover percentage is independent from the other strata. The tree cover is 20 % in one stratum and the grass is 100 % in the other stratum.

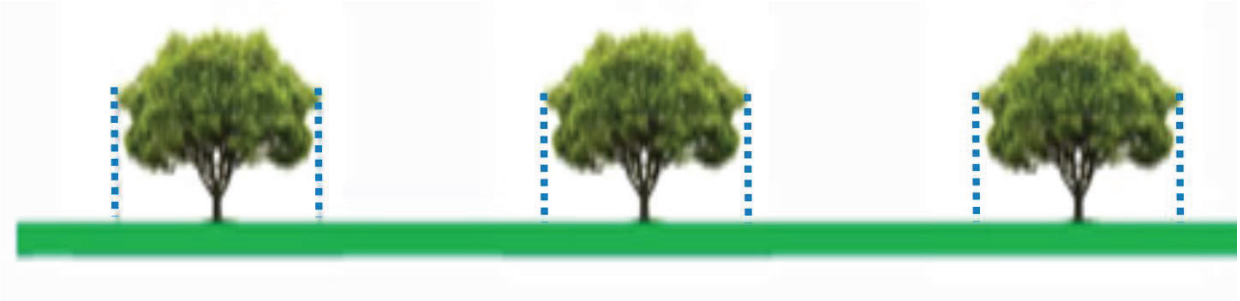

Figure 5 — Example of independent strata

In Figure 6 a vertical relationship can be expressed between elements in different strata. The tree cover is 20 % in one stratum and the grass under trees is also 20 % in the other stratum, with the grass not under trees 80 %.

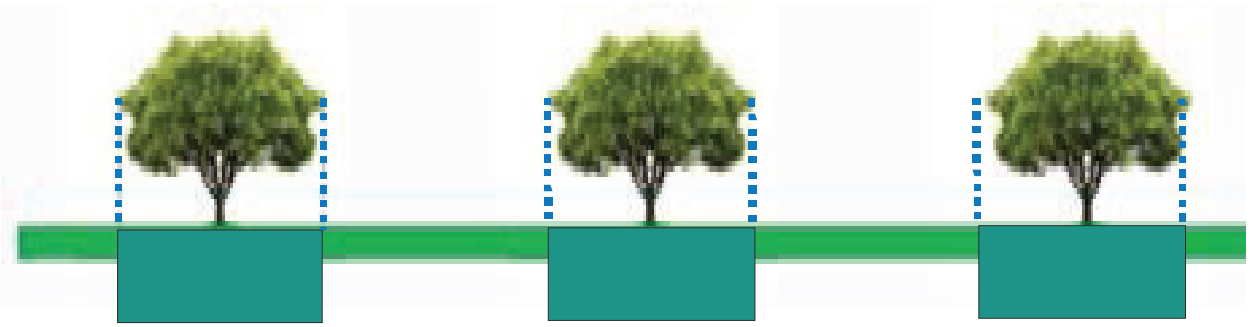

Figure 6 — Example of a vertical relationship between strata

EXAMPLE 1 An example of the first case is the representation of the vegetation formation called “tiger bush” which consists of a combination of patches of open shrubs and patches of open grassland in a specific horizontal pattern. These two LC_Element objects are treated together as one Land Cover object, independent of scale. An example of tiger bush is given in C.2. Using the horizontal pattern construct, a user can indicate that at any scale this object will be always a combination of these two LC_Element objects.

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EXAMPLE 2 An example of the second case occurs when it is necessary to detail the vertical relationship of different elements. In the European Union Common Agricultural Policy there is a need to describe permanent grassland with scattered shrubs and trees which are subject to local agronomic practices (grazing, collection of vegetation usable for forage, reduce tillage, mulching, cleaning up of scrub encroachment). These "mixed" grasslands are called "pro-rata grasslands" and are integral to the "green dimension" of the European Union Common Agricultural Policy. Many European countries, especially in the Mediterranean region, declare presence of such grasslands on their territory and record them spatially and define their typologies in local Land Cover nomenclatures. In certain pro-rata grassland types with denser tree coverage, the vegetation present beneath the woody plants plays an important role in the quantification of the eligible area available, as well as in the evaluation of the contribution of the grassland with respect to environment and climate. An example is given in C.17.

NOTE 3 A horizontal pattern for an object is distinct from the combination of two LC_LandCoverClassDescriptor objects that would otherwise be distinct but are combined because they cannot be distinguished at a given scale.

EXAMPLE 3 Closed trees (classification class A) in a grassland (classification class B) area that, due to the scale of representation of the data, cannot be mapped separately and are therefore combined into a combined class A/B. At other scales, these would be separate Land Cover descriptor metaclasses.

The object LC_HorizontalPattern has three optional attributes: *patternType*, *patternCoverPercentage* and *patternOccurrence*. The permitted values of the attribute *patternType* are described in free text in a character string. The permitted values of the attribute *patternCoverPercentage* are described by the value object LC_PermittedPercentageRange. The permitted values of the attribute *patternOccurrence* are described by the LC_PermittedPercentageRange. The attribute *patternCoverPercentage* describes the percentage of the different horizontal patterns while the attribute *patternOccurrence* describes the range of probability that this pattern is present.

In order to represent Land Cover Legend classes or Application Schema that describe heterogeneous areas, the attribute *patternOccurrence* describes the probability that a certain recurrent feature can be part of the whole class. Any attribute provided in a metalanguage level class is an attribute descriptor, which is a template so that an attribute can be used at a lower level of instantiation.

EXAMPLE 4 In a complex agricultural mosaic, there can be small herbaceous crop fields, small clumps of trees, vineyard fields and ponds. However, the occurrence of ponds is much less frequent than the other three elements. The attribute *patternOccurrence* allows this structure to be described.

The LC_HorizontalPattern object has a composition relationship with the object LC_Stratum through the relation *multiStrataComposition*. This composition relationship is an ordered aggregation of the LC_Stratum elements that make up a horizontal pattern. There is an associated optional relationship class LC_PlanarStrataComposition that carries an attribute *strataPortioning*.

All attributes in LC_HorizontalPattern, and the relationship class LC_StrataPortion are optional. If a class descriptor as represented by LC_LandCoverClassDescriptor contained only a single stratum, then none of these optional attributes would be expressed and the horizontal pattern would be null.

8.6.2.3 LC_PlanarStrataComposition

The relationship multiStrataComposition carries the relationship class LC_PlanarStrataComposition, which has the one optional attribute, *strataPortioning*. This whole relationship class is optional since its only attribute is optional. The attribute *strataPortioning* takes on a percentage value expressing the portion by which the strata comprise a part of the whole.

The aggregate of multiple related strata can be constrained so that the sum of all of the related strata (projected in orthogonal plane) equals 100 %. That is, the portion of each strata together comprise the whole. The portion for each stratum is expressed by the associated relationship class LC_PlanarStrataComposition carrying the attribute *strataPortioning*. The attribute *strataPortioning* takes on a percentage value within a range.

An example of how this structure is used is shown in Figure 7. The same situation of grass and trees as used in the previous figures is shown again. The coverage of the trees is 20 %. The coverage of the grass can be more than 80 % because the grass can grow under the tree canopy, but this information can be

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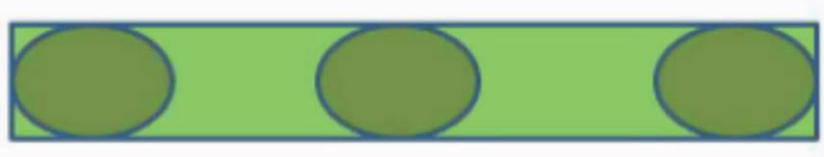
unavailable. For example, the data can have been gathered using data that does not allow one to view below the tree canopy, such as some types of satellite imagery. The portion of the grass in this example is 80 %. The portion and cover are different concepts. Figure 7 shows the trees and grass as seen from above.



NOTE The aggregate sum of the strata portions is ≤ 100 %. The tree cover strata portion is 20 % and the grass strata portion is 80 %.

Figure 7 — Example of planar strata composition

8.6.2.4 LC_Stratum

Individual or groups of Land Cover elements (vegetated and/or non-vegetated) can be assembled into strata (or layers). The LC_Stratum object represents a grouping of Land Cover elements (LC_Element) that make a layer. This layer can then be considered as the definition of a component of an LC_LandCoverClassDescriptor object. Several strata can be combined in an ordered sequence to model specific Land Cover classes in certain environments.

EXAMPLE An example is a savannah or woodland composed by three separate layers of trees, shrubs and herbs with different cover of the woody component of the vegetation types. The cover of the elements in each stratum can overlap since each stratum is independent from each other. Examples of the use of the LC_Stratum and the layering construct are given in Annex C.

The LC_Stratum object can be a component of the description of a Land Cover class in a Land Cover classification system, and can form a component of a Legend class in a Legend derived from that classification system.

This object has three relationships.

— It is an element in the composition relationship *multiLayerComposition* with the LC_HorizontalPattern object.

— It has a composition relationship *multiStrataComposition* with the object LC_Element. Any number of LC_Element (vegetated and/or non-vegetated) can be combined in a stratum. The only constraint on this relationship is that {the sum of the cover of all the LC_Elements within one stratum cannot be more than 100 %}.

— There is an optional *interStrataRelationship* relationship between separate instances of Land Cover class components from the LC_Stratum object. The properties of this relation are given in the association class LC_InterStrataRelationship.

The object LC_Stratum has two optional attributes, which are: name and presenceType. The attribute *name* can be used to describe the stratum. The permitted value of the attribute *name* is in free text in a character string.

The attribute *presenceType* allows one to indicate whether a stratum is fixed (mandatory), i.e. always present in the composition of elements for an LC_LandCoverClassDescriptor metalanguage object, or whether it is conditional. This allows the modelling of a situation where a certain stratum is permitted but not always present in the definition of an LC_LandCoverClassDescriptor metalanguage object, for example, in describing a type of forested area where a stratum containing the object representing a tree is fixed (mandatory) whereas one for a shrub is conditional (optional). The permitted values of the attribute *presenceType* are described by the code list LC_StratumPresenceType. The *presenceType* of conditional is useful when describing a Land Cover classification system that contains classes or

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Legends based on ambiguous definitions or when the intention is to indicate that a further refinement of the Land Cover class is possible. The default value of the attribute *presenceType* is "fixed".

8.6.2.5 LC_InterStrataRelationship

The associated relationship class LC_InterStrataRelationship defines the relationship between instances of the LC_Stratum object. Two or more LC_Elements are required in a stratum to have portioning.

A constraint is that {An instance of LC_Stratum metalanguage object cannot have an interStrataRelationship with itself directly or indirectly through a circular reference}.

The associated relationship class LC_InterStrataRelationship has the optional attribute *onTop*. The permitted values of the attribute *onTop* are defined by the code list LC_OnTopType. The default value is "baseline".

The LC_Stratum object describes a set of Land Cover elements that are assembled into strata (or layers). Several strata can be combined in an ordered sequence. The *onTop* attribute indicates a relationship between strata where one stratum is defined in reference to another. This relationship can either be with respect to a common background such as the soil surface of the Earth, or can be with respect to another strata.

EXAMPLE 1 Three elements: trees, shrubs and herbs can exist in separate stratum and all originate from the same soil background. See C.3 for an example using three strata.

By default, if the *onTop* relationship flag is not specified then all the strata within an LC_LandCoverClassDescriptor metalanguage object have a common background reference. That is, the default relationship is to the common baseline. In cases where the relationship with the background is different. it is necessary to define other values of the *onTop* relationship explicitly.

EXAMPLE 2 A "roof tree garden", could be expressed as a building forming the first stratum with the object tree forming the second stratum on top of the first stratum.

This construct is very useful to describe trees with epiphytes or lianas, boulders with lichen or mosses, etc.

There are two constraints on the *onTop* relationship:

— {if two or more LC_Elements in the stratum are regulated by an exclusive or temporal relationship, LC_Element from the on top stratum goes "on top" of all of the elements regulated by the exclusive or temporal relationship}; and

— {if two or more LC_Elements are regulated by a "conditional" relationship, the LC_Element from the on top stratum goes "on top" of the "fixed" element in the conditional relationship}.

8.6.2.6 LC_Element

The LC_Element object is a generalization of a large number of subtypes. These subtypes form the basic elements of the LCML metalanguage model. A classification system, described in terms of the metalanguage, consists of Land Cover classes formed as serializations of the LCML metalanguage model LC_Element subtypes in various combinations.

The object LC_Element is "pure", i.e. it is composed of single concept independent Land Cover metalanguage-elements.

If the LC_Element object is used with no subtypes, it describes an area with no data.

The attribute *presenceType* makes it possible to indicate whether an LC_Element in a stratum is fixed (mandatory), i.e. always present in the composition of elements for an LC_Stratum and indirectly for a LC_LandCoverClassDescriptor metalanguage object, or whether it is exclusive, conditionalTemporal or precluded. The permitted values of the attribute *presenceType* are described by LC_ElementPresenceType. This attribute has a default value of "fixed". The attribute *elementPortioning*

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represents the percent value, within a range, of the area of pertinence of a single LCML basic element when two or more LCML basic elements are considered in the same stratum. The sum of the whole portioning values for all elements considered within a stratum is always equal to 100 %.

This object has three relationships.

— It is an element in the ordered relationship *multiStrataComposition* with LC_Stratum.

— There is a *sequentialTemporalRelationship* between separate instances of the LC_Element objects. The elements in the same stratum are regulated by four different relationship statuses: Fixed, Exclusive, Conditional and Sequential Temporal, as described in LC_ElementPresenceType which is a code list for the attribute *presenceType* in the UML association class LC_ElementRelationInSameStratum.

— There is a composition relationship where LC_ElementHorizontalArrangement is a component of LC_Element. The LC_Element object is purely physiognomic and LC_ElementHorizontalArrangement is additional information regarding the horizontal structure of that element over the ground.

The constraint on the relationship *multiStrataComposition* is that {the sum of the cover of all the LC_Elements within one stratum cannot be more than 100 %}.

The constraint on the *sequentialTemporalRelationship* is that {an LC_Element can have a sequentialTemporalRelationship only with the next one in the ordered list of LC_LandCoverElements which belong to the same LC_Stratum}.

8.6.2.7 LC_ElementRelationInSameStratum

The UML association class LC_ElementRelationInSameStratum defines the relationship between instances of the LC_Element object.

The UML association class LC_ElementRelationInSameStratum has two optional attributes: *temporalType* and *lengthOfTemporalRelationship*.

The attribute *temporalType* is optional. If the attribute exists it indicates whether a sequential temporal relationship exists. This structure allows the modelling of a situation where a certain LC_Element is permitted but not always present in the definition of an LC_Stratum and indirectly an LC_LandCoverClassDescriptor metalanguage object (i.e. it is optional), and also a situation where one of two LC_Elements is permitted but not both (exclusive OR — XOR).

The attribute *temporalType* for the UML association class LC_ElementRelationInSameStratum is optional and by default there is no sequential temporal relation. This attribute allows the indication of a temporal relationship between LC_Elements. One element can exist at one time and another element at a different time (see C.10).

The attribute *lengthOfTemporalRelationship* in the UML association class LC_ElementRelationInSameStratum describes the length of the temporal relationship using a value object representing a positive real range. For “sequentialSameYear” value of the attribute *temporalType*, the value is measured in months. For “sequentialOtherYear” value of the attribute *temporalType*, the value is measured in years. See 8.28.2.7 for a description of LC_PermittedPosRealRange.

Optionality is useful when describing a Land Cover classification system that contains classes or Legends based on ambiguous definitions or for indicating that a further refinement of the Land Cover class is possible.

NOTE The UML association class LC_ElementRelationInSameStratum is optional and the two attributes *temporalType* and *lengthOfTemporalRelationship* within that class are also optional. If the LC_ElementRelationInSameStratum class is used without any attributes it has the same meaning as not using the LC_ElementRelationInSameStratum class.

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8.6.2.8 LC_ElementHorizontalArrangement

The optional component LC_ElementHorizontalArrangement provides for a description of the structural aspect of an LC_Element. The structural aspect in general describes both the horizontal and vertical aspect/relationship of the LC_Element. The use of stratum (LC_Stratum) describes the vertical relationship and object LC_HorizontalPattern describes the horizontal relationship of LC_Elements within a stratum. The LC_ElementHorizontalArrangement describes the horizontal aspect within an LC_Element. These properties are characterized by three attribute types: *cover*, *density* (with associated *densityUnitOfMeasure*) and *elementHorizontalSpreading*.

The attribute *cover* describes the area of incidence of an element over the bare ground. The permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageRange.

The attribute *density* is the number of LC_Elements in an area defined using a specific unit of measure (e.g. elements per hectare). The attribute *density* is expressed as a real number in terms of a unit of measure given in the attribute UnitOfMeasure taking on the value type *UomArea*.

The attribute *densityUnitOfMeasure* gives the value type *UomArea* for the attribute *density*.

The attribute *elementHorizontalSpreading* describes the horizontal structure of that element over the ground.

8.6.2.9 LC_ElementHorizontalSpreadingType

The code list LC_ElementHorizontalSpreadingType contains a list of types of horizontal structure of an element over the ground. The code list values are:

— unevenlySpread — The LC_BasicElement types are erratically dispersed over the ground. The spreading is uniform. It is a typical disposition of growth forms of natural vegetation or artificial or natural elements that do not have an artificial (human-induced) disposition pattern;

— regularRowsGeneral — The LC_BasicElement types are arranged in systematic, ordered rows or strips;

— regularRowsSingleElement — The LC_BasicElement types are arranged in systematic, ordered rows or strips. The row is formed by a line of a single type of LC_Basic Element;

— regularMultipleSingleElement — The LC_BasicElement types are arranged in systematic, ordered rows or strips. The row is formed by two or more adjacent lines of two or more LC_Basic Element types;

— clusters — The components of the LC_BasicElement are arranged in groups that form a specific pattern over their overall irregular disposition;

— other — The LC_BasicElement types are arranged in another manner.

This list can be extended through registration.

8.6.2.10 LC_StratumPresenceType

The code list LC_StratumPresenceType contains a list of types of stratum relationships (see 8.6.2.4). This list contains three types: fixed,optional and conditional. This list can be extended through registration. The attribute *presenceType* for the UML association class LC_InterStrataRelationship is optional and is by default the first value of this enumeration, namely “fixed”. The presence types are:

— fixed — The LC_Stratum is always present in the LC_HorizontalPattern and indirectly in the LC_LandCoverClassDescriptor metalanguage object;

— optional — The presence of an LC_Stratum can optionally exist;

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— conditional — The existence of the LC_Stratum is dependant upon the temporal existence of the element composing the strata.

8.6.2.11 LC_ElementPresenceType

The code list LC_ElementPresenceType contains a list of types of element relationships (see 8.6.2.6). This list contains four types: fixed, exclusive, conditional and precluded. This list can be extended through registration. The attribute presenceType for the UML association class LC_ ElementRelationInSameStratum is optional and is by default the first value of this enumeration "fixed". The presence types are:

— fixed — The LC_Element exists in the stratum;

— exclusive — One of two or more LC_Elements can exist in the stratum (XOR relationship) linked with a sequential temporal relationship;

— conditionalTemporal — The existence of an LC_Element in a stratum can optionally exist and is regulated by a temporal relationship. It is dependant upon a temporal relationship being defined;

— precluded — When the absence of an LC_Element is explicitly stated.

Two or more LC_Elements can exist in a stratum in an exclusive (XOR) relationship linked with a sequential temporal relationship. For instance, it is possible to model in a very detailed way a situation concerning when and for how long one field remains with bare ground or with crop, or when in a field there are two crops and related harvest periods in the same field. The two crops grow in a sequential order. It is also possible to model fallow land that remains as fallow for one or two years and in the third year the land is cultivated. See C.10.

8.6.2.12 LC_SequentialTemporalRelationshipType

The code list *LC_SequentialTemporalRelationshipType* contains a list of types of temporal relationships. This list contains two types: *sequentialSameYear* and *sequentialOtherYear*. This list can be extended through registration.

8.6.2.13 LC_OnTopType

The code list LC_OnTopType contains a list of types of on-top relationships for the *onTop* attribute of the LC_InterStrataRelationship association class (see 8.6.2.6). The "onTop" relationship make use of a code list in order to make it possible to define as many values as wanted, and to give them explicit meanings. This is the most flexible approach to handling the "onTop" relation. This list contains nine types. This list can be extended through registration. The attribute *onTopType* for the UML association class LC_ InterStrataRelationship is optional and is by default the first value of this enumeration "baseline". The on top relationship types are:

— baseline — Elements of a stratum are "on top" of the baseline, where the baseline is a reference surface which corresponds to the surface of the earth (or water) covered by the Land Cover features that are instantiations of the LC_LandCoverClassDescriptor metalanguage object. Baseline is the default value of the relationship onTop;

— previousE1 — Elements of a stratum are "on top" of the first element (or set of elements regulated by an exclusive, temporal or conditional relationship) of the previous stratum;

— previousE2 — Elements of a stratum are "on top" of the second element (or set of elements regulated by an exclusive, temporal or conditional relationship) of the previous stratum;

— previousE3 — Elements of a stratum are "on top" of the third element (or set of elements regulated by an exclusive, temporal or conditional relationship) of the previous stratum;

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— previousE1-2 — Elements of a stratum are “on top” of the first to second elements of the previous stratum (where either the first and /or second element can be a set of elements regulated by an exclusive, temporal or conditional relationship);

— previousAll — Elements of a stratum are “on top” of all the elements of the previous stratum;

— stratum1E1 — Elements of a stratum are “on top” of the first element (or set of elements regulated by an exclusive, temporal or conditional relationship) of the first stratum defined in the set of stratum which are components of the LC_LandCoverClassDescriptor metalanguage object;

— stratum1All — Elements of a stratum are “on top” of all of the elements of the first stratum defined in the set of stratum which are components of the LC_LandCoverClassDescriptor metalanguage object;

— stratum2E1 — Elements of a stratum are “on top” of the first element (or set of elements regulated by an exclusive, temporal or conditional relationship) of the second stratum defined in the set of stratum which are components of the LC_LandCoverClassDescriptor metalanguage object;

— stratum2All — Elements of a stratum are “on top” of all of the elements of the first stratum defined in the set of stratum which are components of the LC_LandCoverClassDescriptor metalanguage object.

NOTE Other relations such as previousE4, previousE2-5, stratum3E4, etc., which are logical extensions of the predefined relations can be defined through registration by the user. However, they are not predefined in this document for reasons of simplicity and because such complex relations would be used infrequently.

8.7 LC_Element

8.7.1 LC_Element subtypes

The LC_Element metalanguage object has two subtypes representing the two basic types of Land Cover and the optional component LC_ElementHorizontalArrangement. This is represented in Figure 8.

The metalanguage operates by representing Land Cover classes in a Land Cover classification system in terms of the subtypes of LC_Element or set of LC_Element(s), with associated attributes and characteristics. That is, a particular Land Cover class in a Land Cover classification system can be modelled by the metalanguage objects in the LCML and compared with another Land Cover class in a different Land Cover classification system by examining the relationship between the models of the two classes in the metalanguage representations.

EXAMPLE A particular concept can have a detailed explicit classification class in one Land Cover classification system but it can only be able to represent it by a more general classification class in another Land Cover classification system. In this case it would be easy to determine from the representations of the two Land Cover classification systems in the LCML that one classification class was a specialization of the other.

In order for the LCML to operate, it is necessary to have definitions for the elements in the metalanguage. The classes in different Land Cover classification systems are modelled with respect to these definitions and so the metalanguage objects in the LCML cannot be vague. Definitions of the subtypes of LC_Element are given in the glossary in Annex D. These are not prescriptive definitions and do not limit the definitions that can be used in any Land Cover classification system. They are a set of reference definitions for the LCML that can be used to facilitate translations or comparisons.

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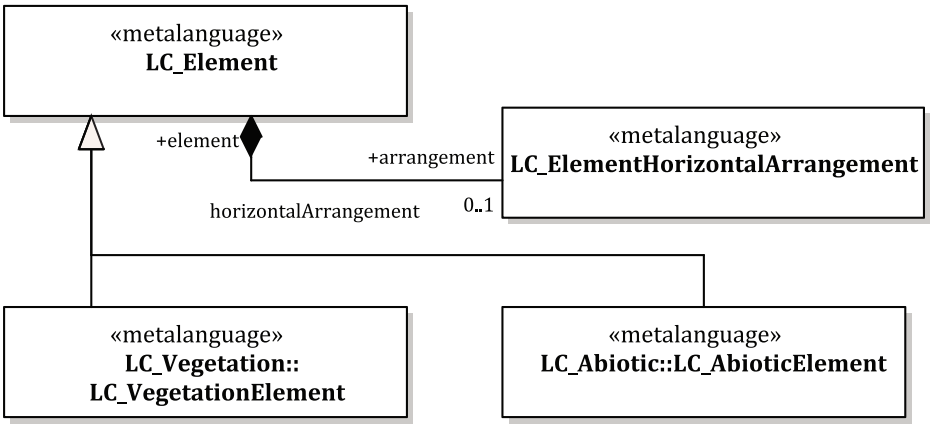

Figure 8 — Subtypes of LC_LandCoverElement

The optional component LC_ElementHorizontalArrangement allows for the description of the horizontal arrangement within an LC_Element.

8.7.2 LC_Element classes

8.7.2.1 LC_VegetationElement

The LC_VegetationElement metalanguage object is a subtype of LC_Element and represents one of the basic types of Land Cover that can be used in a Land Cover classification system. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation-covered surfaces.

8.7.2.2 LC_AbioticElement

The LC_AbioticElement metalanguage object is a subtype of LC_Element and represents one of the basic types of Land Cover that can be used in a Land Cover classification system. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all abiotic surfaces.

8.8 LC_VegetationElement

8.8.1 LC_VegetationElement subtypes

The LC_VegetationElement metalanguage object is a subtype of LC_Element. It has one subtype, LC_GrowthForm, and has a relationship *growthFormCharacteristics* to a component LC_LandCoverElementCharacteristic. This is represented in Figure 9.

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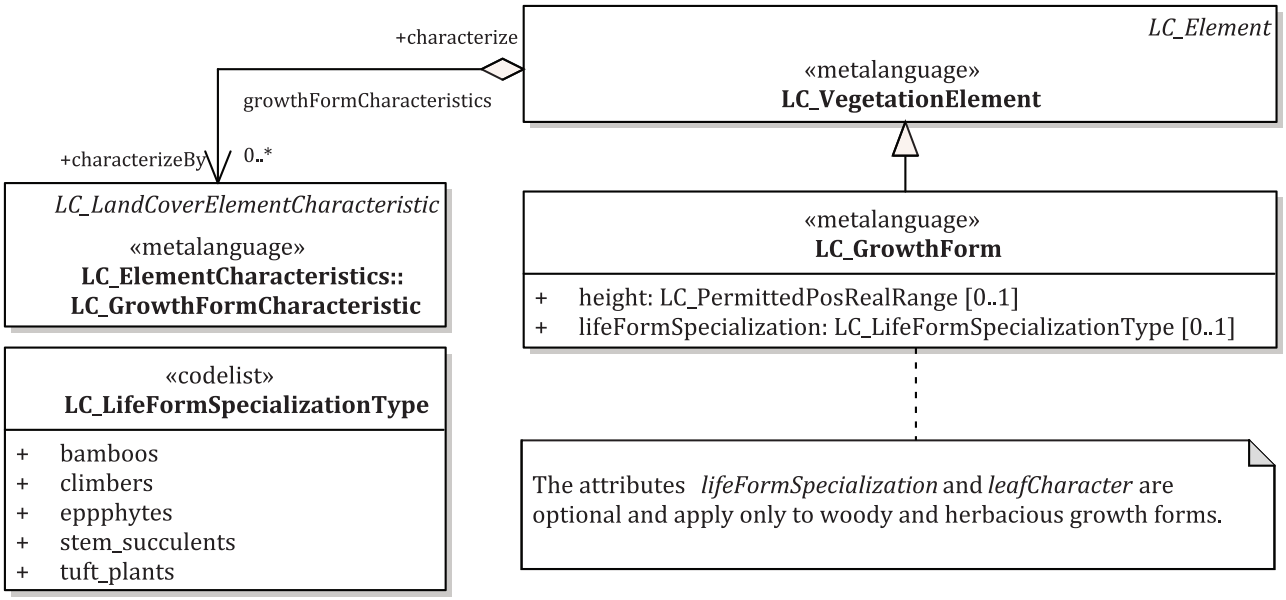

Figure 9 — Subtypes of LC_VegetationElement

8.8.2 LC_VegetationElement classes

8.8.2.1 LC_GrowthForm

The LC_GrowthForm metalanguage object is a subtype of LC_VegetationElement. It has two optional attributes: *height* and *lifeFormSpecialization*. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealRange. The permitted values of the attribute *lifeFormSpecialization* are described by the codelist LC_LifeFormSpecializationType. The attribute *height* describes the height of the growth form in the units used in the data set.

8.8.2.2 LC_LifeFormSpecializationType

LC_LifeFormSpecializationType is a code list used to to refine the description of the physiognomic aspect. It refers to specific traits of vegetation contributing to its further definition. It is categorized in five different types:

— bamboos: bamboos are a type of grass with a woody stem;

— climbers (lianas): the term is used to name all the plants that climb trees and shrubs;

— ephiphytes: plants which grows upon other plants. In effect it is not a specific physiognomic aspect but more a structural one;

— stem succulents: plants with a specific succulent stem (barrel cacti in semi-arid regions is an example);

— tuft plants: plants usually with an unbranched trunk wich carries at its apex a tuft of leaves (most of the palms).

This list may be extended through registration.

NOTE Taxonomically speaking bamboos are grasses, but because they are woody growth forms they are inserted into the woody plant section.

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8.8.2.3 LC_GrowthFormCharacteristic

The component LC_GrowthFormCharacteristic is related to the LC_VegetationElement metalanguage object by the relation *growthFormCharacteristics*. The component LC_GrowthFormCharacteristic can be used to refine the metalanguage object LC_VegetationElement or any of its subtypes to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.9 LC_GrowthForm

8.9.1 LC_GrowthForm subtypes

The LC_GrowthForm metalanguage object is a subtype of LC_VegetationElement and has four subtypes: LC_WoodyGrowthForm, LC_HerbaceousGrowthForm, LC_LichenAndMoss and LC_Algae. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all growth form vegetation-covered surfaces. This is represented in Figure 10.

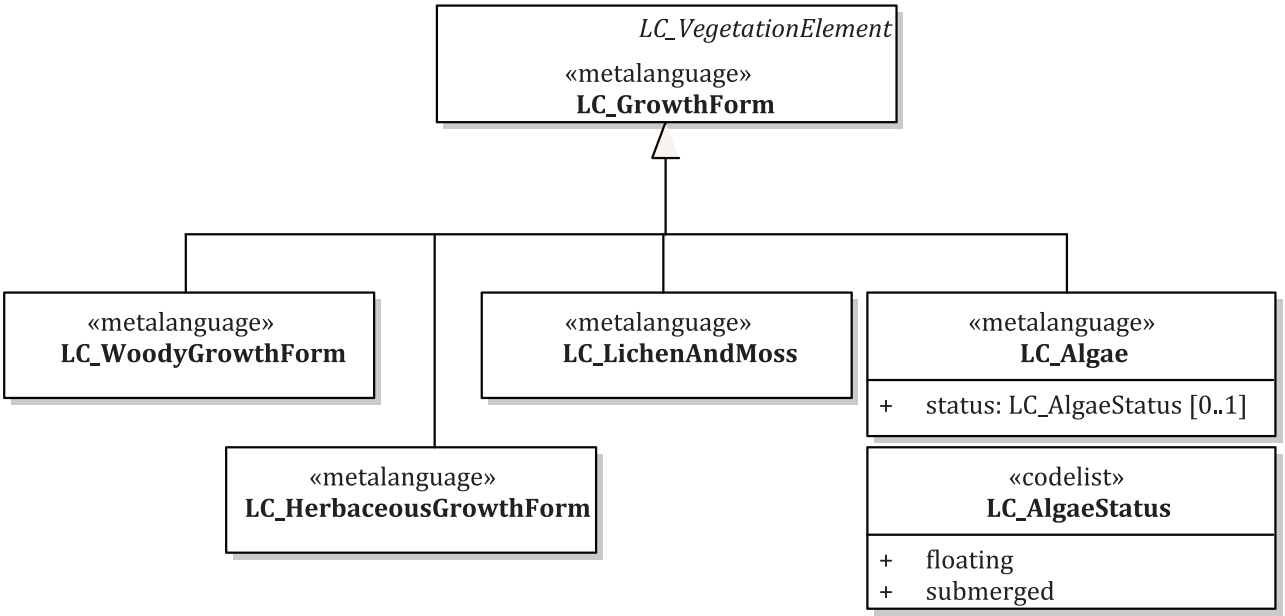

Figure 10 — Subtypes of LC_GrowthForm

8.9.2 LC_GrowthForm classes

8.9.2.1 LC_WoodyGrowthForm

The LC_WoodyGrowthForm metalanguage object is a subtype of LC_GrowthForm. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation-covered surfaces where the cover is a woody growth form.

8.9.2.2 LC_HerbaceousGrowthForm

The LC_HerbaceousGrowthForm metalanguage object is a subtype of LC_GrowthForm. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation-covered surfaces where the cover is a herbaceous growth form.

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8.9.2.3 LC_LichenAndMoss

The LC_LichenAndMoss metalanguage object is a subtype of LC_GrowthForm. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation-covered surfaces where the cover is a lichen and/or moss.

8.9.2.4 LC_Algae

The LC_Algae metalanguage object is a subtype of LC_GrowthForm. It has one optional attribute: *status*. The permitted values of the attribute *status* are described by the code list LC_AlgaeStatus. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation-covered surfaces where the cover is algae.

8.9.2.5 LC_AlgaeStatus

The code list LC_AlgaeStatus contains a list of algae status. This list contains two types:

— floating: floating algae;

— submerged: submerged algae.

This list can be extended through registration.

8.10 LC_WoodyGrowthForm

8.10.1 LC_WoodyGrowthForm subtypes

The LC_WoodyGrowthForm metalanguage object is a subtype of LC_GrowthForm and has two subtypes: LC_Tree and LC_Shrub; and two components: LC_WoodyLeafType and LC_WoodyLeafPhenology. The relationship *leafType* is to LC_WoodyLeafType and the relationship *leafPhenology* is to LC_WoodyLeafPhenology.

This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all woody growth form vegetation-covered surfaces. This is represented in Figure 11.

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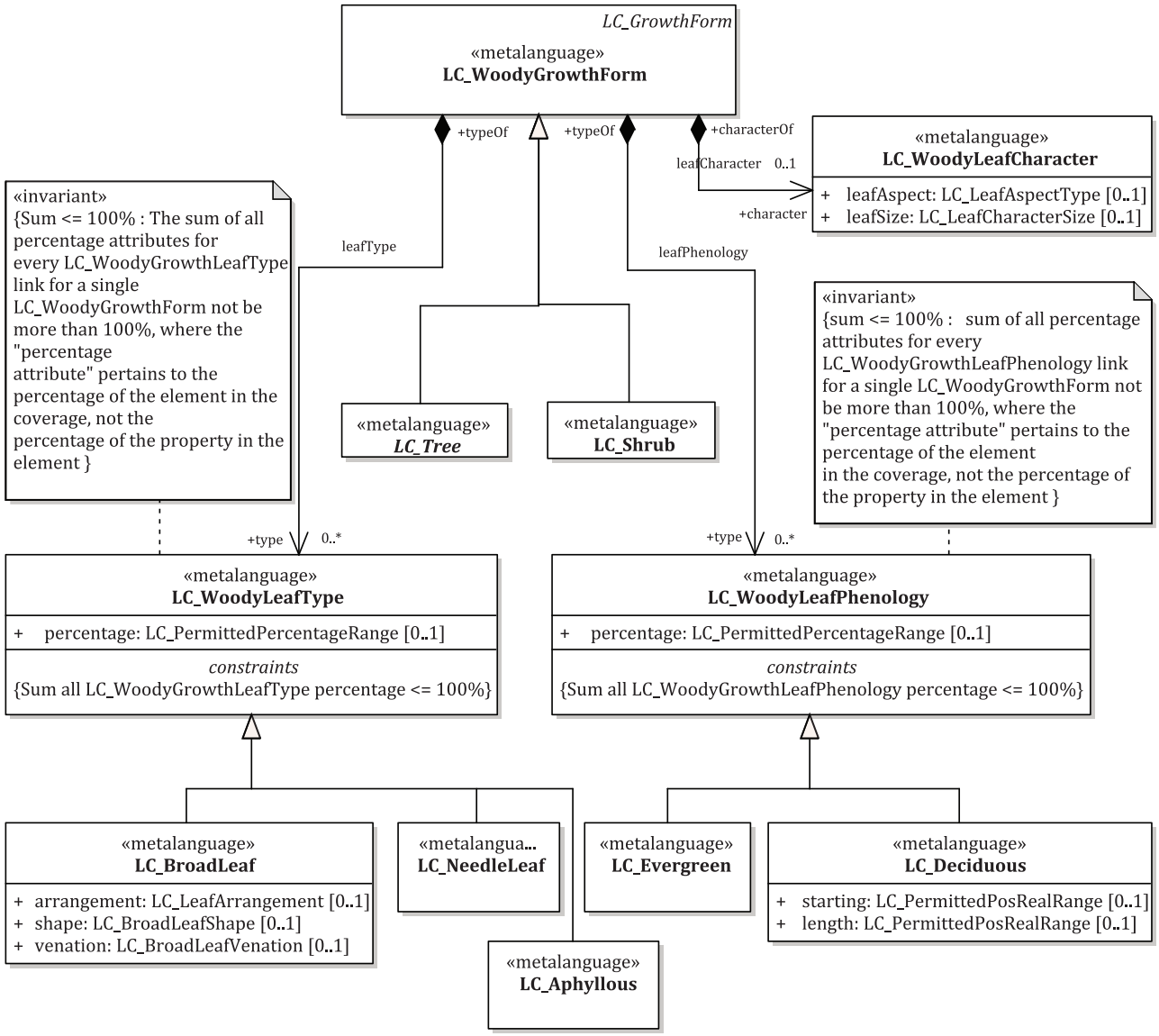

Figure 11 — Subtypes of LC_WoodyGrowthForm

The code lists that support LC_WoodyGrowthForm and its components are shown in Figure 12.

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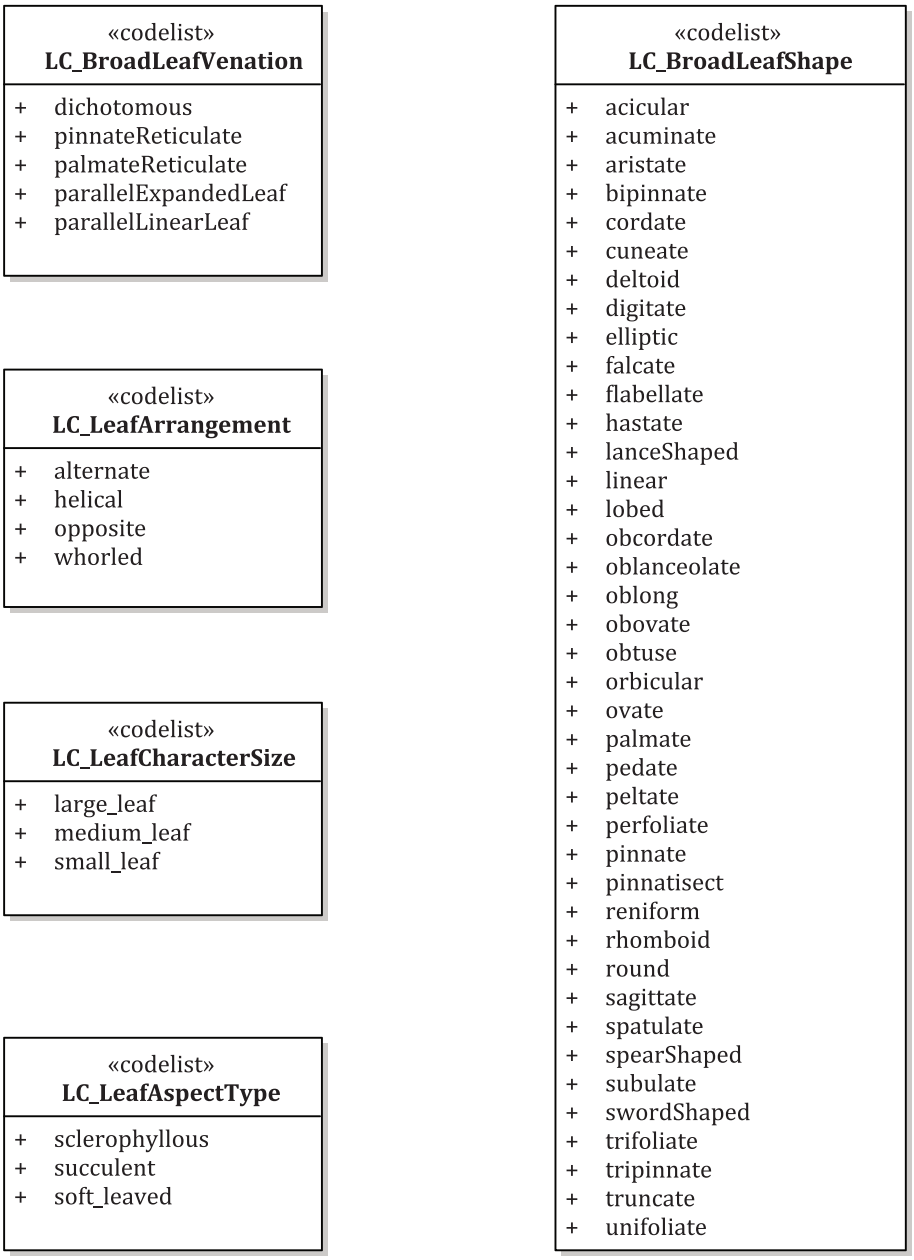

Figure 12 — Code lists that support the LC_WoodyGrowthForm object structure

8.10.2 LC_WoodyGrowthForm classes

8.10.2.1 LC_Tree

The LC_Tree metalanguage object is a subtype of LC_WoodyGrowthForm. It has a constraint on the *height* attribute inherited from LC_GrowthForm of a certain threshold in height. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all tree-covered surfaces.

NOTE The height threshold is described in Annex D.

8.10.2.2 LC_Shrub

The LC_Shrub metalanguage object is a subtype of LC_WoodyGrowthForm. It has a constraint on the *height* attribute inherited from LC_GrowthForm of a certain threshold in height. This metalanguage

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object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all shrub-covered surfaces.

NOTE The height threshold is described in Annex D.

8.10.2.3 LC_WoodyLeafType

The component LC_WoodyLeafType is related to LC_WoodyGrowthForm by the relation *leafType*. It has three subtypes: LC_NeedleLeaf, LC_Aphyllous and LC_BroadLeaf. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange with the constraint that {it is required that the sum of all percentage attributes for every LC_WoodyGrowthLeafType link for a single LC_WoodyGrowthForm be not more than 100 %}. The concept of percentage pertains to the percentage of the element in the coverage, not the percentage of the property in the element. The component LC_WoodyLeafType can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.4 LC_BroadLeaf

The LC_BroadLeaf metalanguage object is a subtype of LC_WoodyLeafType. The properties of broadleaf leaves can be further characterized by leaf "Arrangement" on the stem, leaf "Shape" and leaf "Venations". This is represented by the three optional attributes *arrangement*, *shape* and *venation*. The permitted values of the attributes *arrangement*, *shape* and *venation* are described by the enumerated value objects LC_LeafArrangement, LC_BroadLeafShape, and LC_BroadleafVenation, respectively. Additional attributes can be established through registration. This sub-component can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.5 LC_NeedleLeaf

The LC_NeedleLeaf metalanguage object is a subtype of LC_WoodyLeafType. Attributes can be established through registration. This sub-component can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.6 LC_Aphyllous

The LC_Aphyllous metalanguage object is a subtype of LC_WoodyLeafType. Attributes can be established through registration. This sub-component can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.7 LC_WoodyLeafPhenology

The component LC_WoodyLeafPhenology is related to WoodyGrowthForm by the relation *leafPhenology*. It has two subtypes: LC_Deciduous and LC_Evergreen. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange with the constraint that {it is required that the sum of all percentage attributes for every LC_WoodyGrowthLeafPhenology link for a single LC_WoodyGrowthForm be not more than 100 %}. The concept of percentage pertains to the percentage of the element in the coverage, not the percentage of the property in the element. The component LC_WoodyLeafPhenology can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.8 LC_Evergreen

The LC_Evergreen metalanguage object is a subtype of LC_WoodyLeafPhenology. Attributes can be established through registration. This sub-component can be used to refine the metalanguage object

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LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.9 LC_Deciduous

The LC_Deciduous metalanguage object is a subtype of LC_WoodyLeafPhenology. It has two optional attributes: *starting* and *length*. The permitted values of the attributes *starting* and *length* are described by the value object LC_PermittedPosRealRange. This sub-component can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. The attribute *starting* describes the time at which a plan generates new leaves. The attribute *length* describes the duration of the persistence of the leaves on a plant. The Unit of Measure (uom) for these two attributes is by default months. This can be changed by the use of the *uom* attribute to the value object LC_PermittedPosIntegerRange. The value of *starting* uses January as month 1.

8.10.2.10 LC_LeafArrangement

The code list LC_LeafArrangement contains a list of leaf arrangements. At the metalanguage level this list is representative and can be extended through registration. The detailed values are described in Annex D.

8.10.2.11 LC_BroadLeafShape

The code list LC_BroadLeafShape contains a list of broadleaf shapes. At the metalanguage level this list is representative and can be extended through registration. The detailed values are described in Annex D.

8.10.2.12 LC_BroadLeafVenation

The code list LC_BroadLeafVenation contains a list of broadleaf venation which describes the arrangement of the veins on the leaf. At the metalanguage level this list is representative and can be extended through registration. The detailed values are described in Annex D.

8.10.2.13 LC_WoodyLeafCharacter

The component LC_WoodyLeafCharacter is related to LC_WoodyGrowthForm by the relation *leafCharacter*. It has two optional attributes: *leafAspect* and *leafSize*. The permitted values are described in the code lists LC_LeafCharacterSize and LC_LeafAspectType. The component LC_WoodyLeafCharacter can be used to refine the metalanguage object LC_WoodyGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.10.2.14 LC_ LeafAspectType

The code list LC_LeafAspectType contains a list of leaf types. This list can be extended through registration.

The values are:

— sclerophyllous: “leather like” leaves;

— succulent: fleshy leaves that are always striking in their appearance due to their water content;

— soft-leaved: soft leaves (the common state).

8.10.2.15 LC_LeafCharacterSize

The code list LC_LeafCharacterSize contains a list of leaf size ranges.

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The values are:

— large: > 400 cm^2;

— medium: (4 – 400) cm^2;

— small: > 4 cm^2.

8.11 LC_HerbaceousGrowthForm

8.11.1 LC_HerbaceousGrowthForm subtypes

The LC_HerbaceousGrowthForm metalanguage object is a subtype of LC_GrowthForm. It has two subtypes: LC_Graminoids and LC_Forbs. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation covered surfaces where the cover is an herbaceous growth form. This is represented in Figure 13.

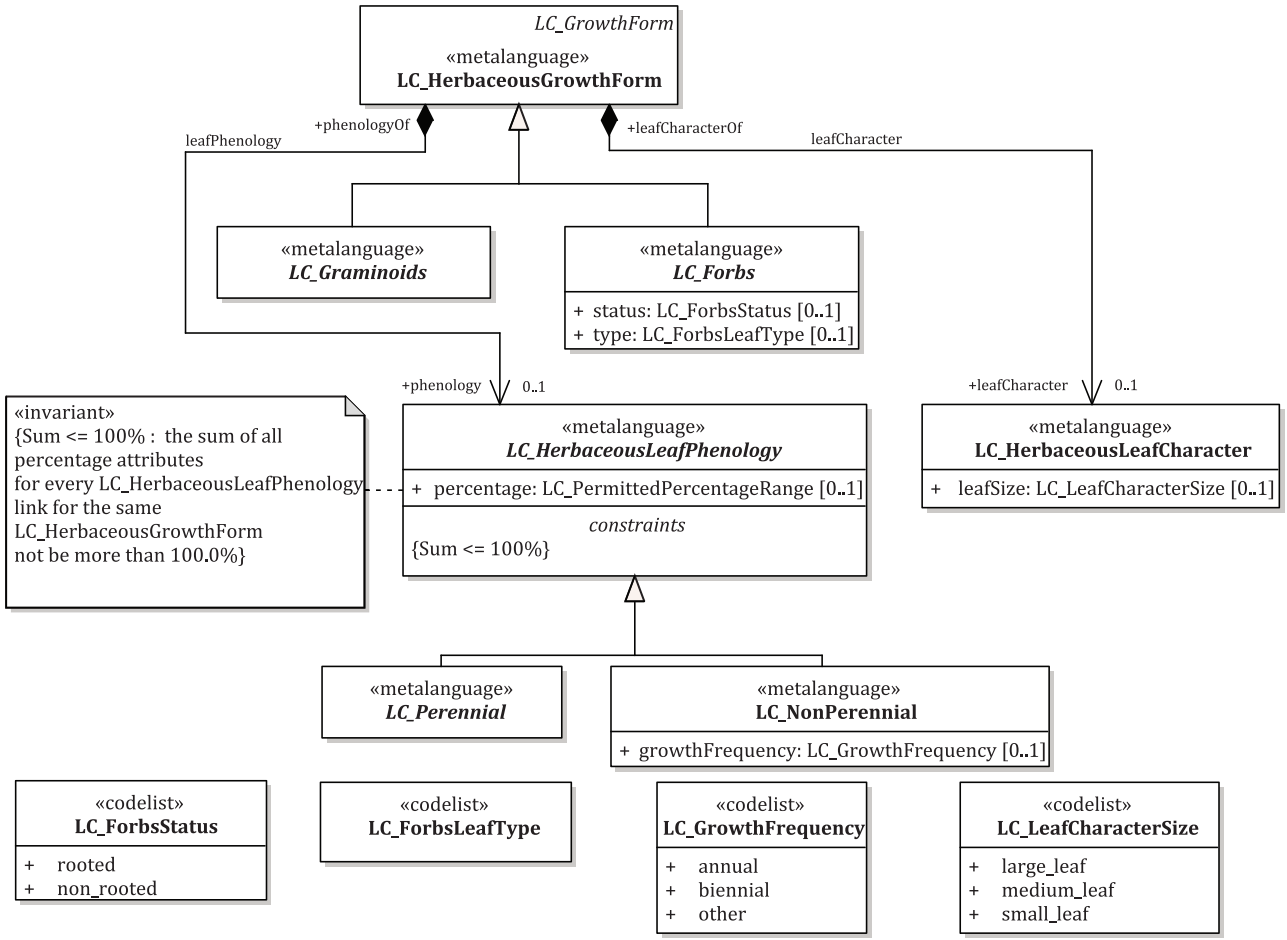

Figure 13 — Subtypes of LC_HerbaeceousGrowthForm

8.11.2 LC_HerbaceousGrowthForm classes

8.11.2.1 LC_Graminoids

The LC_Graminoids metalanguage object is a subtype of LC_HerbaceousGrowthForm. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all graminoid herbaceous growth form covered surfaces.

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8.11.2.2 LC_Forbs

The LC_Forbs metalanguage object is a subtype of LC_HerbaceousGrowthForm. It has two optional attributes: *status* and *type*. The permitted values of the attribute *status* are described by the enumerated values UML class LC_ForbsStatus. The permitted values of the attribute *type* are described by the code list LC_ForbsLeafType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all forbs herbaceous growth form covered surfaces.

8.11.2.3 LC_HerbaceousLeafPhenology

The component LC_HerbaceousLeafPhenology is related to LC_HerbaceousGrowthForm by the relation leafPhenology. It has three subtypes: LC_Annual, LC_Biennial and LC_Perennial. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange, with the constraint that {it is required that the sum of all percentage attributes for every LC_HerbaceousLeafPhenology link for the same LC_HerbaceousGrowthForm be not more than 100.0 %}. The component LC_HerbaceousLeafPhenology can be used to refine the metalanguage object LC_HerbaceousGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.11.2.4 LC_HerbaceousLeafCharacter

The component LC_HerbaceousLeafCharacter is related to LC_HerbaceousGrowthForm by the relation *leafCharacter*. It has one optional attribute: *leafSize*. The permitted values are described in the code list LC_LeafCharacterSize. The component LC_HerbaceousLeafCharacter can be used to refine the metalanguage object LC_HerbaceousGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.11.2.5 LC_LeafCharacterSize

The code list LC_LeafCharacterSize contains a list of leaf size ranges. See 8.10.2.15.

8.11.2.6 LC_Perennial

The LC_Perennial metalanguage object is a subcomponent of LC_HerbaceousLeafPhenology. Attributes can be established through registration. This sub-component can be used to refine the metalanguage object LC_HerbaceousGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.11.2.7 LC_NonPerennial

The LC_NonPerennial metalanguage object is a subcomponent of LC_HerbaceousLeafPhenology. Attributes can be established through registration. This sub-component can be used to refine the metalanguage object LC_HerbaceousGrowthForm to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. It has one optional attribute: *growthFrequency*. The permitted values of the attribute *growthFrequency* are described by the enumerated values in UML class LC_GrowthFrequency. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all forbs herbaceous growth form covered surfaces.

8.11.2.8 LC_ForbsStatus

The code list LC_ForbsStatus contains a list of forbs status types. This list contains two types:

— rooted: has roots;

— non_rooted: does not have roots.

This list can be extended through registration.

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8.11.2.9 LC_ForbsLeafType

The code list LC_ForbsLeafType contains a list of leaf types. At the metalanguage level this list is empty, but it can be populated through registration.

8.11.2.10 LC_GrowthFrequency

The code list LC_GrowthFrequency contains a list of frequencies for HerbaeceousGrowthForm life cycles. This list contains three types:

— annual: yearly;

— biennial: every two years;

— other: other life cycle frequency.

This list can be extended through registration.

8.12 LC_LichenAndMoss

8.12.1 LC_LichenAndMoss subtypes

The LC_LichenAndMoss metalanguage object is a subtype of LC_GrowthForm. It has two subtypes: LC_Lichen and LC_Moss. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all vegetation-covered surfaces where the cover is a lichen and/or moss growth form. This is represented in Figure 14.

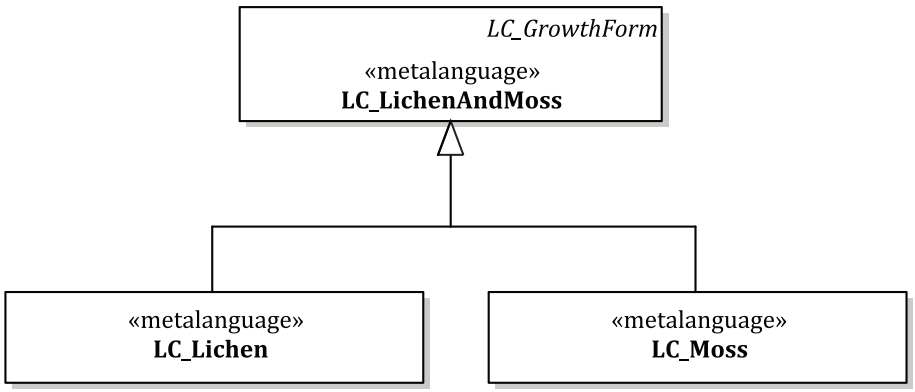

Figure 14 — Subtypes of LC_LichenAndMoss

8.12.2 LC_LichenAndMoss classes

8.12.2.1 LC_Lichen

The LC_Lichen metalanguage object is a subtype of LC_LichenAndMoss. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all lichen-covered surfaces.

8.12.2.2 LC_Moss

The LC_Moss metalanguage object is a subtype of LC_LichenAndMoss. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all moss-covered surfaces.

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8.13 LC_AbioticElement

8.13.1 LC_AbioticElement subtypes

The LC_AbioticElement metalanguage object is a subtype of LC_Element and has three subtypes representing the three basic types of abiotic surface Land Cover. The subtypes are: LC_ArtificialSurfaceElement, LC_NaturalSurfaceElement and LC_WaterBodyAndAssociatedSurfaceElement. This is represented in Figure 15.

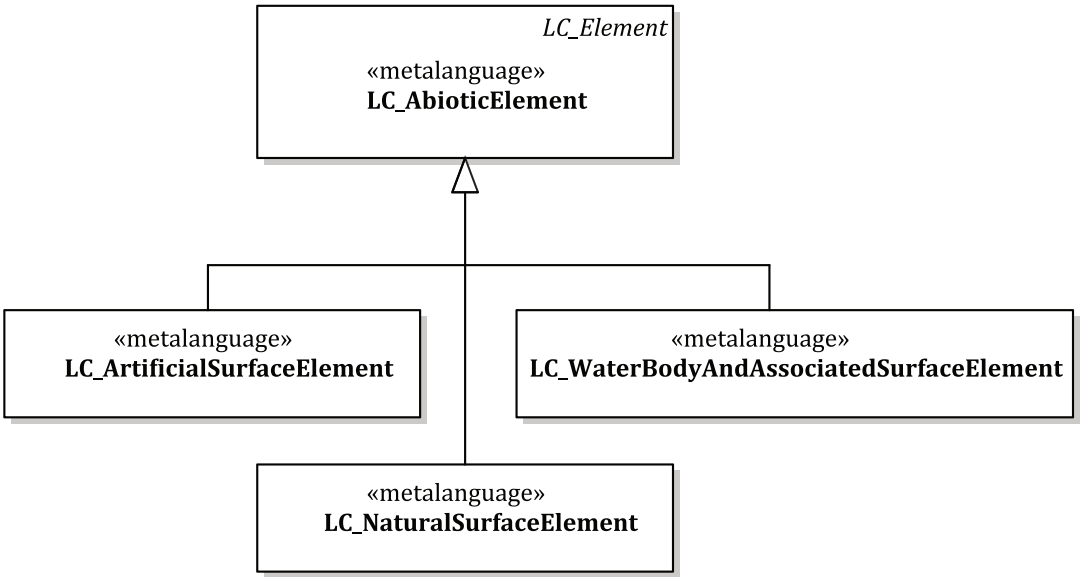

Figure 15 — Subtypes of LC_AbioticElement

8.13.2 LC_AbioticElement classes

8.13.2.1 LC_ArtificialSurfaceElement

The LC_ArtificialSurfaceElement metalanguage object is a subtype of LC_AbioticElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all artificial surfaces that are built-up and non-built-up.

8.13.2.2 LC_NaturalSurfaceElement

The LC_NaturalSurfaceElement metalanguage object is a subtype of LC_AbioticElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all natural surfaces.

8.13.2.3 LC_WaterBodyAndAssociatedSurfaceElement

The LC_WaterBodyAndAssociatedSurfaceElement metalanguage object is a subtype of LC_AbioticElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all water body and associated surfaces.

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8.14 LC_ArtificialSurfaceElement

8.14.1 LC_ArtificialSurfaceElement subtypes

The LC_ArtificialSurfaceElement metalanguage object has two subtypes: LC_BuiltUpSurface and LC_NonBuiltUpSurface. It also has a relationship with the component LC_ArtificialSurfaceCharacteristic. This is represented in Figure 16.

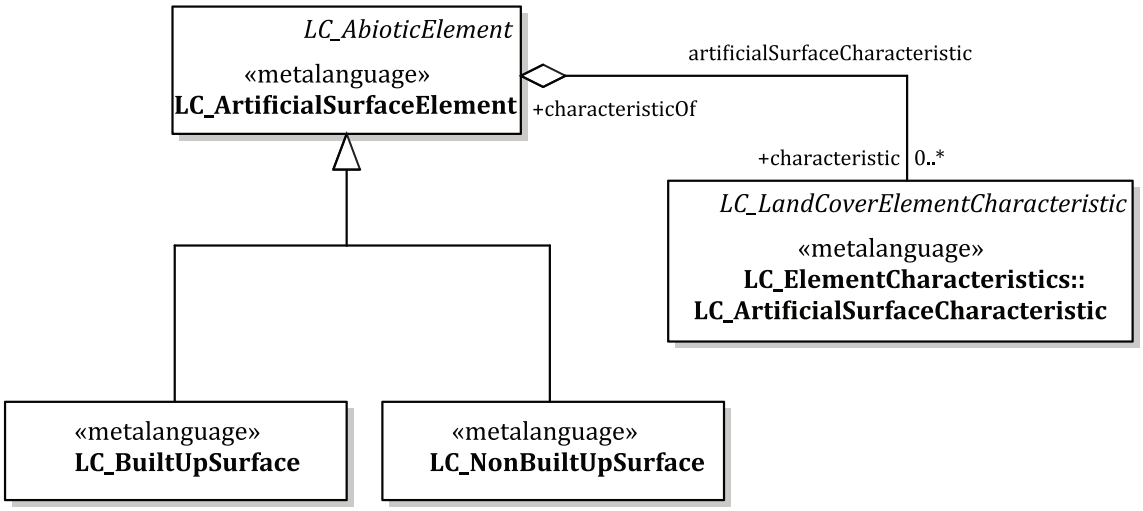

Figure 16 — Subtypes of LC_ArtificialSurfaceElement

8.14.2 LC_ArtificialSurface classes

8.14.2.1 LC_BuiltUpSurface

The LC_BuiltUpSurface metalanguage object is a subtype of LC_ArtificialSurfaceElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all built-up surfaces.

8.14.2.2 LC_NonBuiltUpSurface

The LC_NonBuiltUpSurface metalanguage object is a subtype of LC_ArtificialSurfaceElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all non-built-up surfaces.

8.14.2.3 LC_ArtificialSurfaceCharacteristic

The component LC_ArtificialSurfaceCharacteristic is related to the LC_ArtificialSurfaceElement metalanguage object by the relation artificialSurfaceCharacteristic. The component LC_ArtificialSurfaceCharacteristic can be used to refine the metalanguage object LC_ArtificialSurfaceElement to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.15 LC_NaturalSurfaceElement

8.15.1 LC_NaturalSurfaceElement subtypes

The LC_NaturalSurfaceElement metalanguage object has two subtypes: LC_RocksSurfaceElement and LC_SoilSandDepositsSurfaceElement. This is represented in Figure 17.

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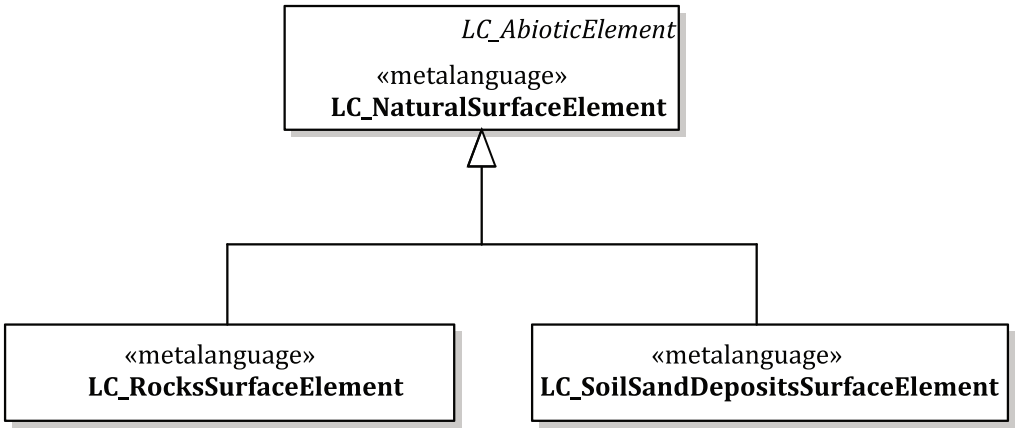

Figure 17 — Subtypes of LC_NaturalSurfaceElement

8.15.2 LC_NaturalSurfaceElement classes

8.15.2.1 LC_RocksSurfaceElement

The LC_RocksSurfaceElement metalanguage object is a subtype of LC_NaturalSurfaceElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all rock natural surfaces. A Rock Surface Element is a geologically consolidated formation.

8.15.2.2 LC_SoilSandDepositsSurfaceElement

The LC_SoilSandDepositsSurfaceElement metalanguage object is a subtype of LC_NaturalSurfaceElement. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all unconsolidated sediment natural surfaces.

8.16 LC_WaterBodyAndAssociatedSurfaceElement

8.16.1 LC_WaterBodyAndAssociatedSurfaceElement subtypes

The LC_WaterBodyAndAssociatedSurfaceElement metalanguage object is a subtype of LC_AbioticElement. It has three subtypes: LC_WaterBody, LC_Snow and LC_Ice. It has a relationship to two components: LC_WaterAndAssociatedSurfaceCharacteristic and LC_PeriodicVariation. This is represented in Figure 18.

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