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Geographic information — Classification systems —

Part 2: Land Cover Meta Language (LCML)

Information géographique — Systèmes de classification —
Partie 2: Métalangage pour l'occupation des sols (LCML)

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Foreword

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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).

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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).

— 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.

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.

— 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.

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.

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.

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]

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

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
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.

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 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 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.

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.

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.

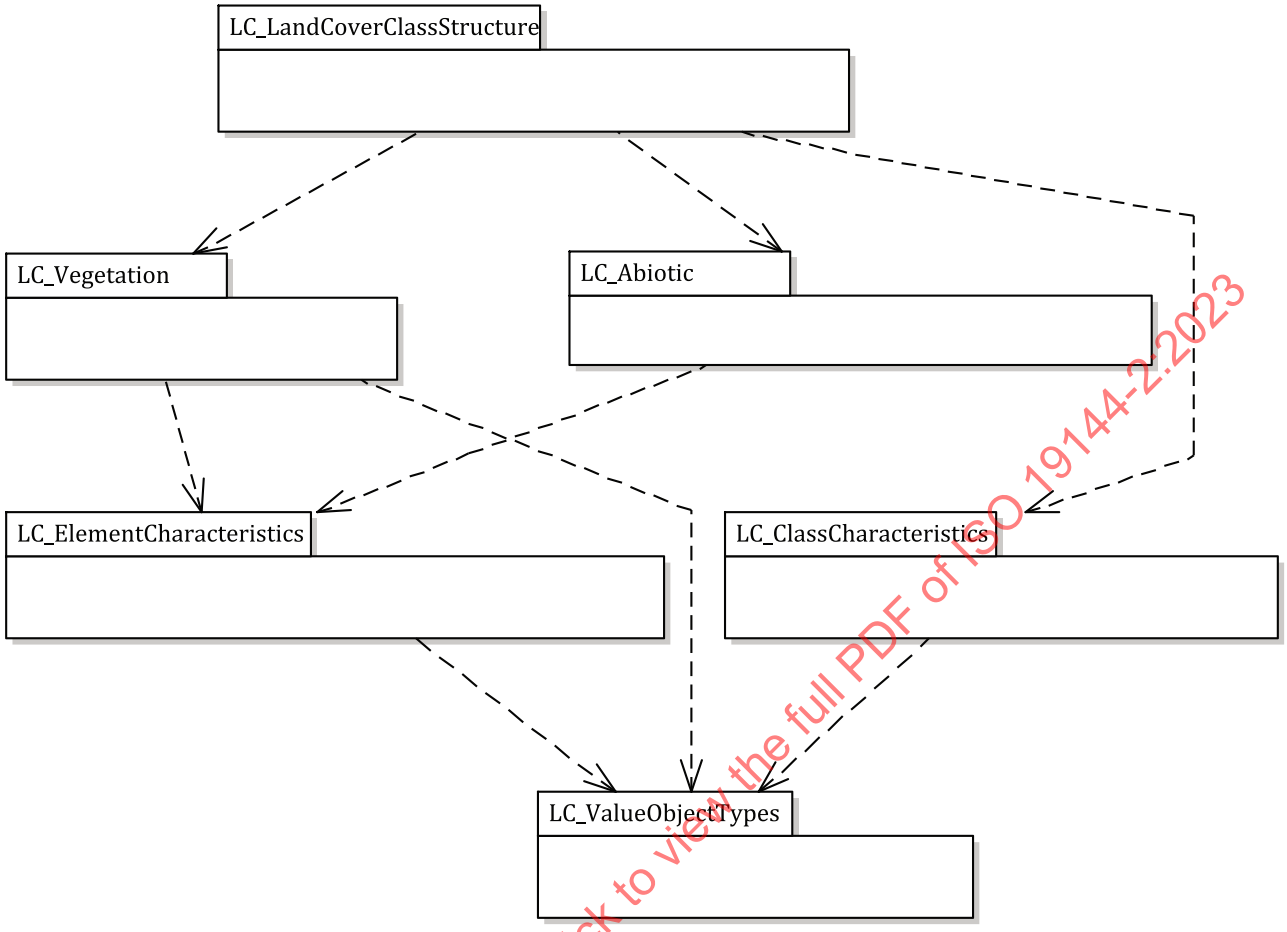


Figure 1 — LCML packages

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.

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.

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.

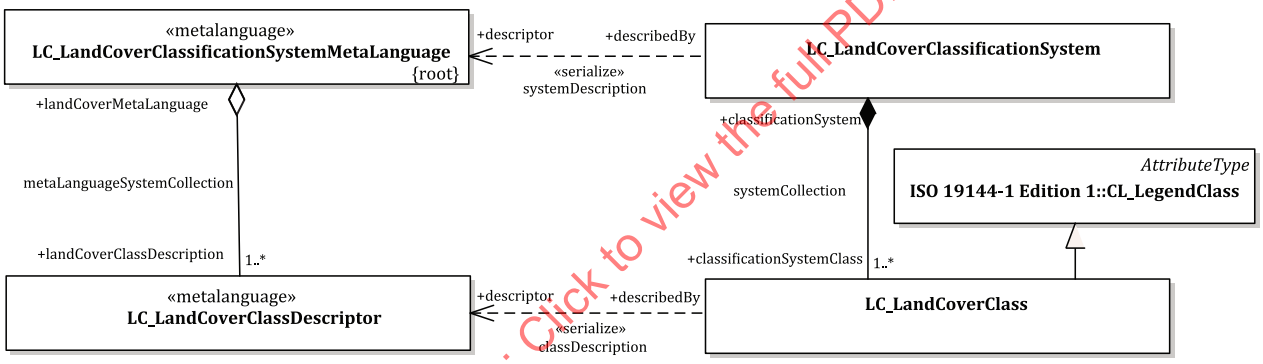


Figure 2 — High level structure of the Land Cover Classification model

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.

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

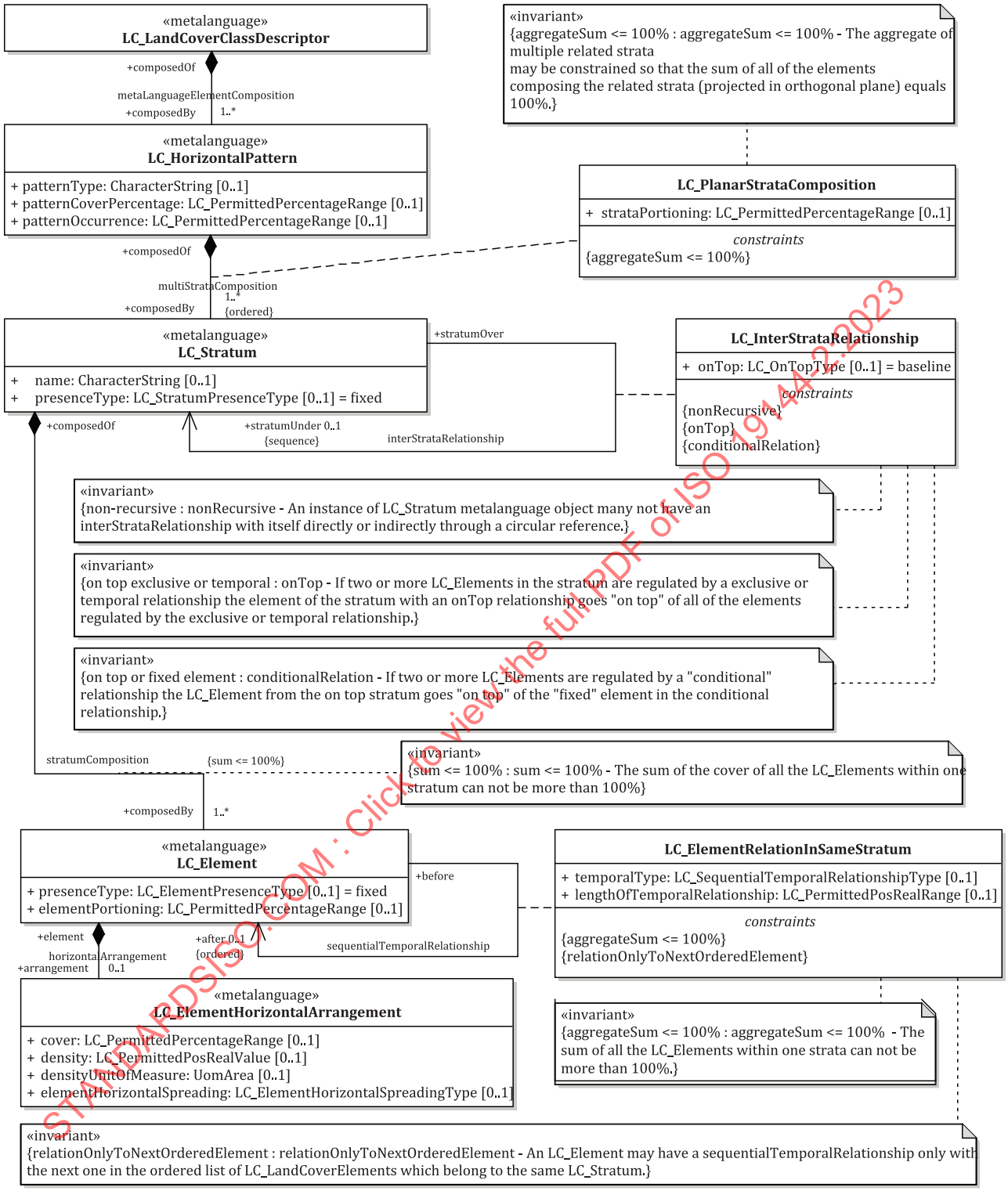


Figure 3 — Land Cover Meta Language object structure

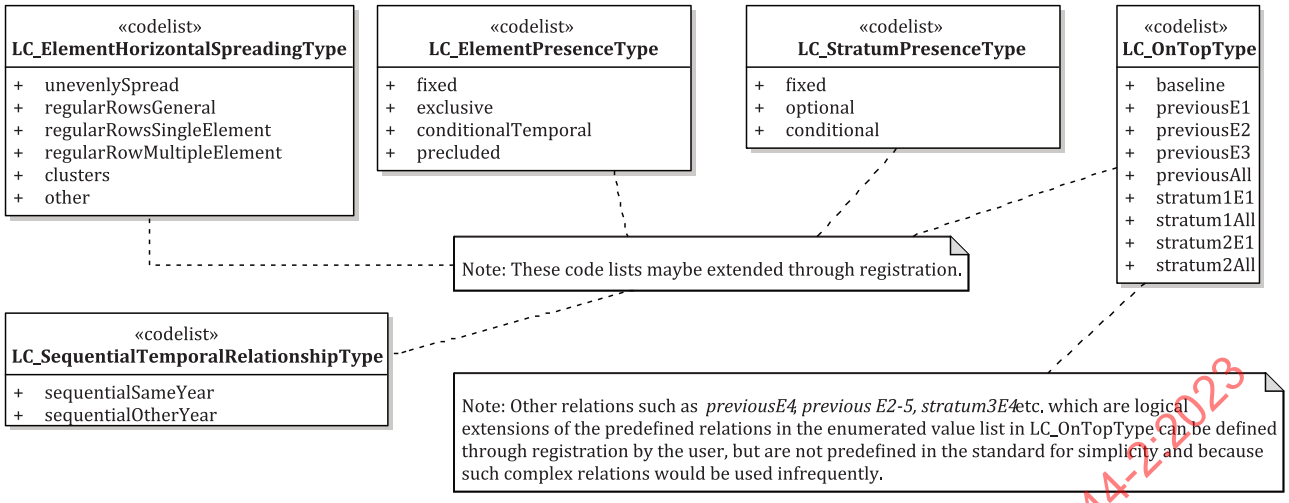


Figure 4 — Code lists that support the Land Cover Meta Language object structure

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 description of the vertical/horizontal relationship of the basic elements constituting a specific Land Cover feature.

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.

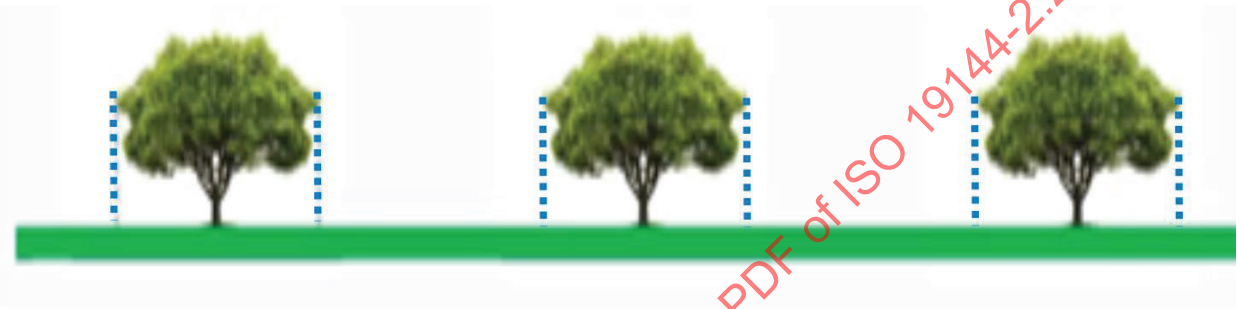


Figure 5 — Example of independent strata

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 %.

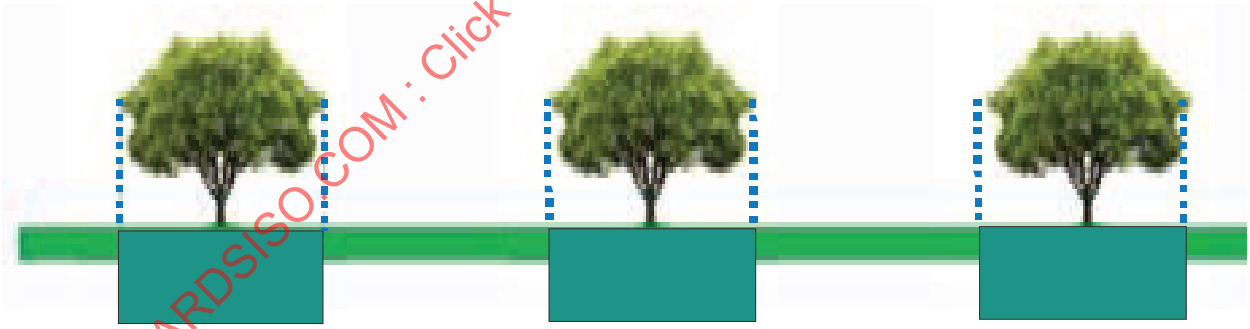


Figure 6 — Example of a vertical relationship between strata

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.

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.

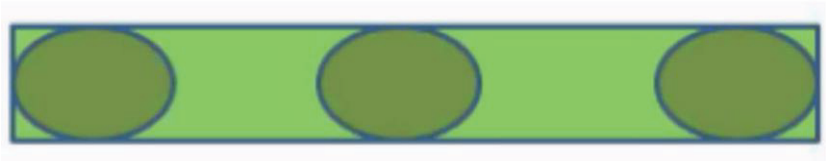
8.6.2.3 LC_PlanarStrataComposition

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 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 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* 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.

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;

— 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;

— 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.

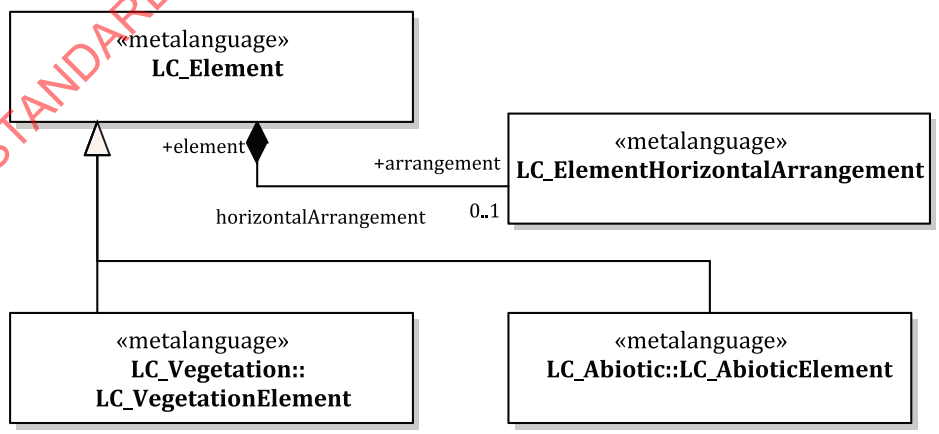


Figure 8 — Subtypes of LC_LandCoverElement

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.

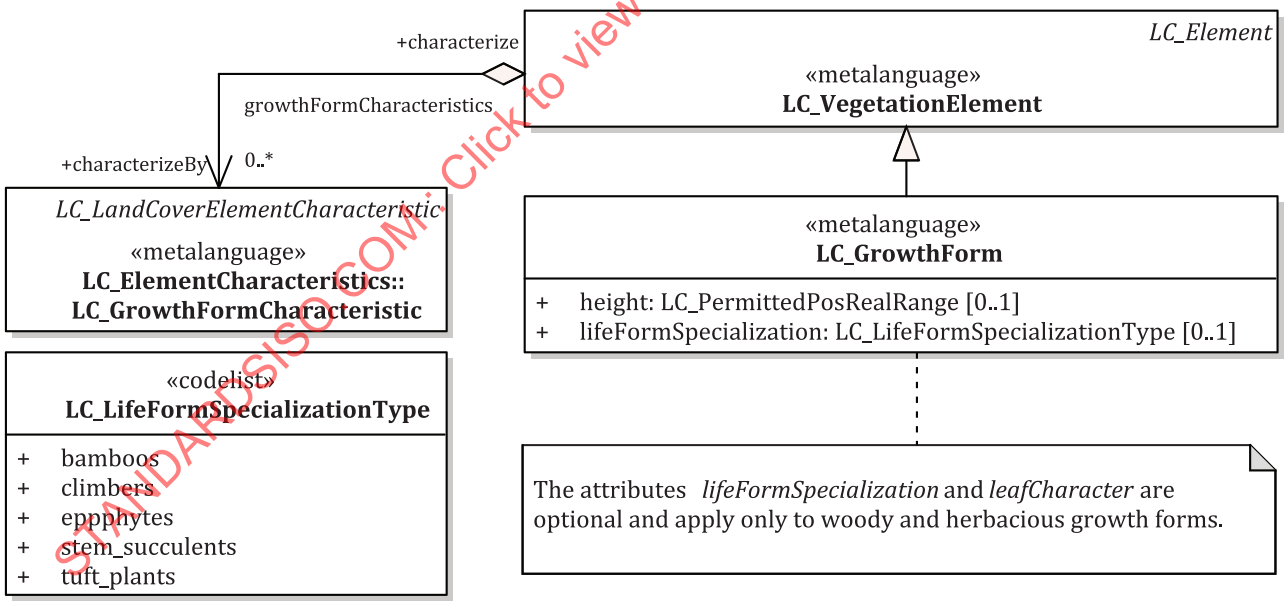


Figure 9 — Subtypes of LC_VegetationElement

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.

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.

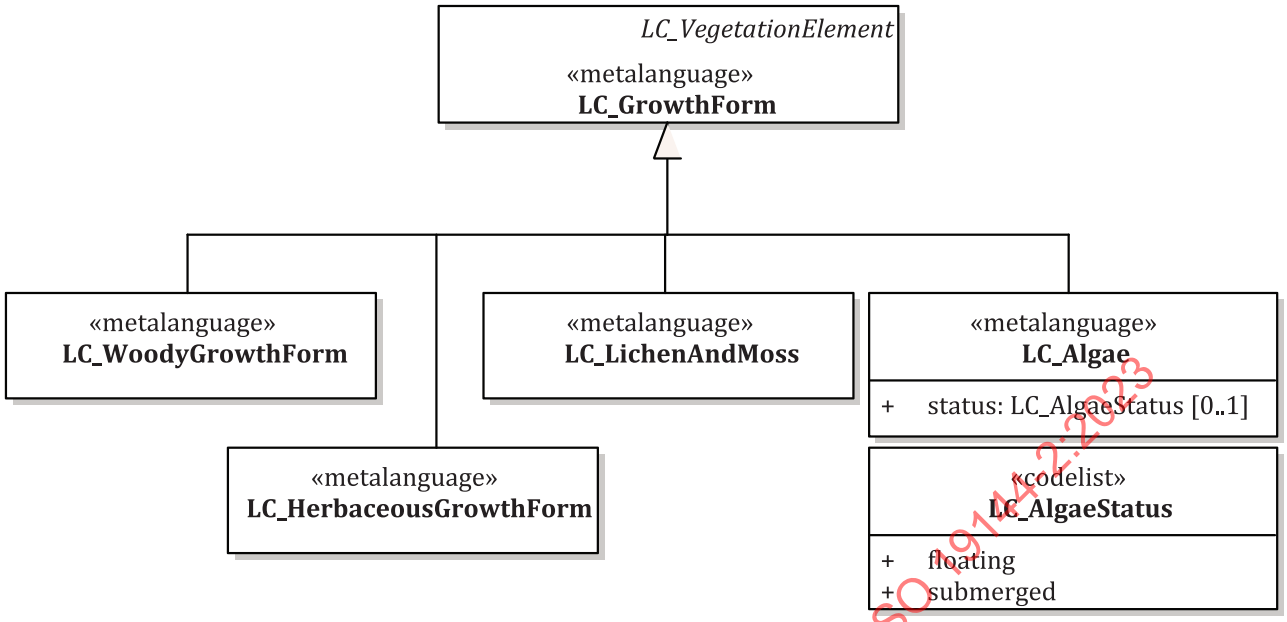


Figure 10 — Subtypes of LC_GrowthForm

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.

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.

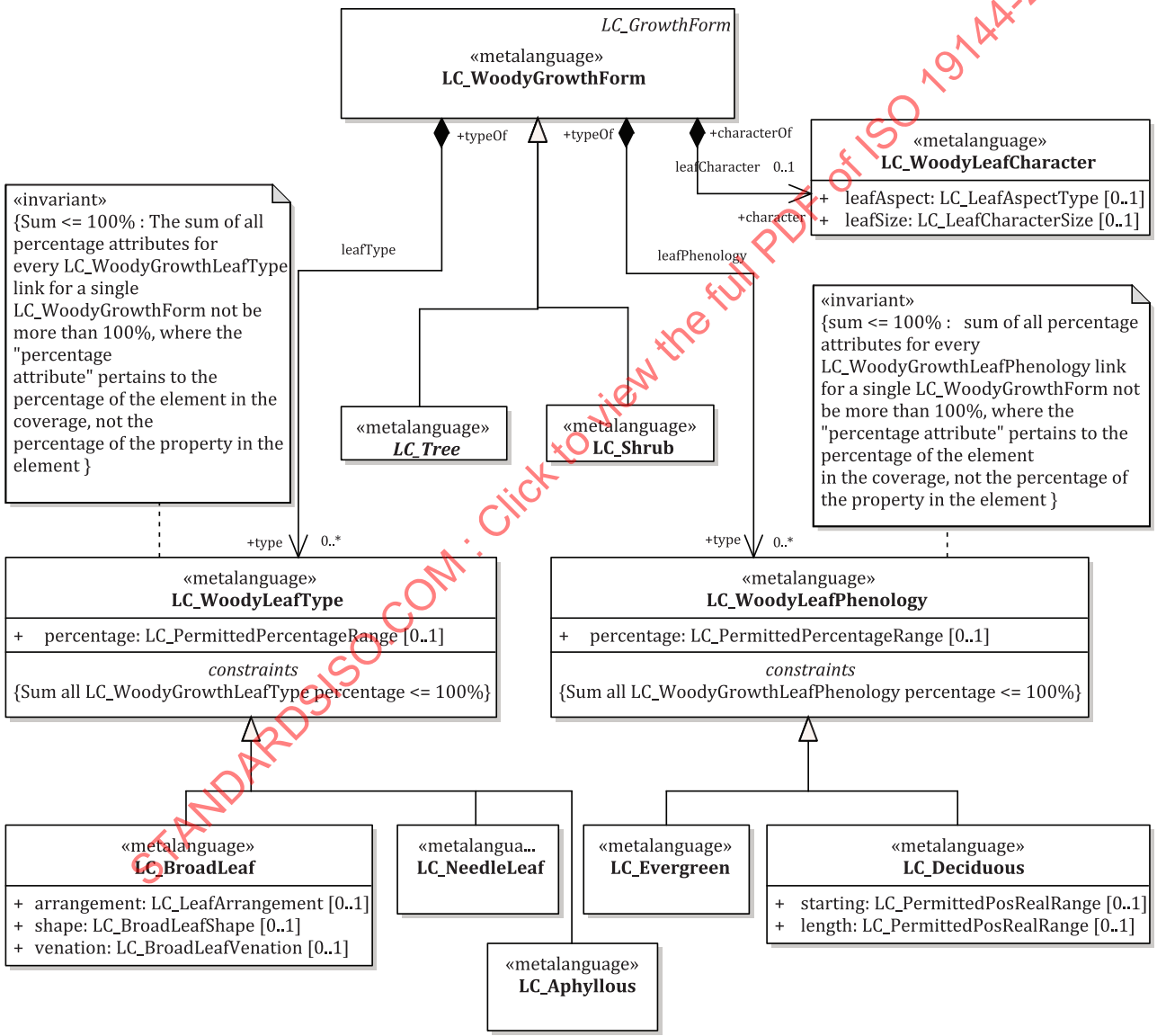


Figure 11 — Subtypes of LC_WoodyGrowthForm

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

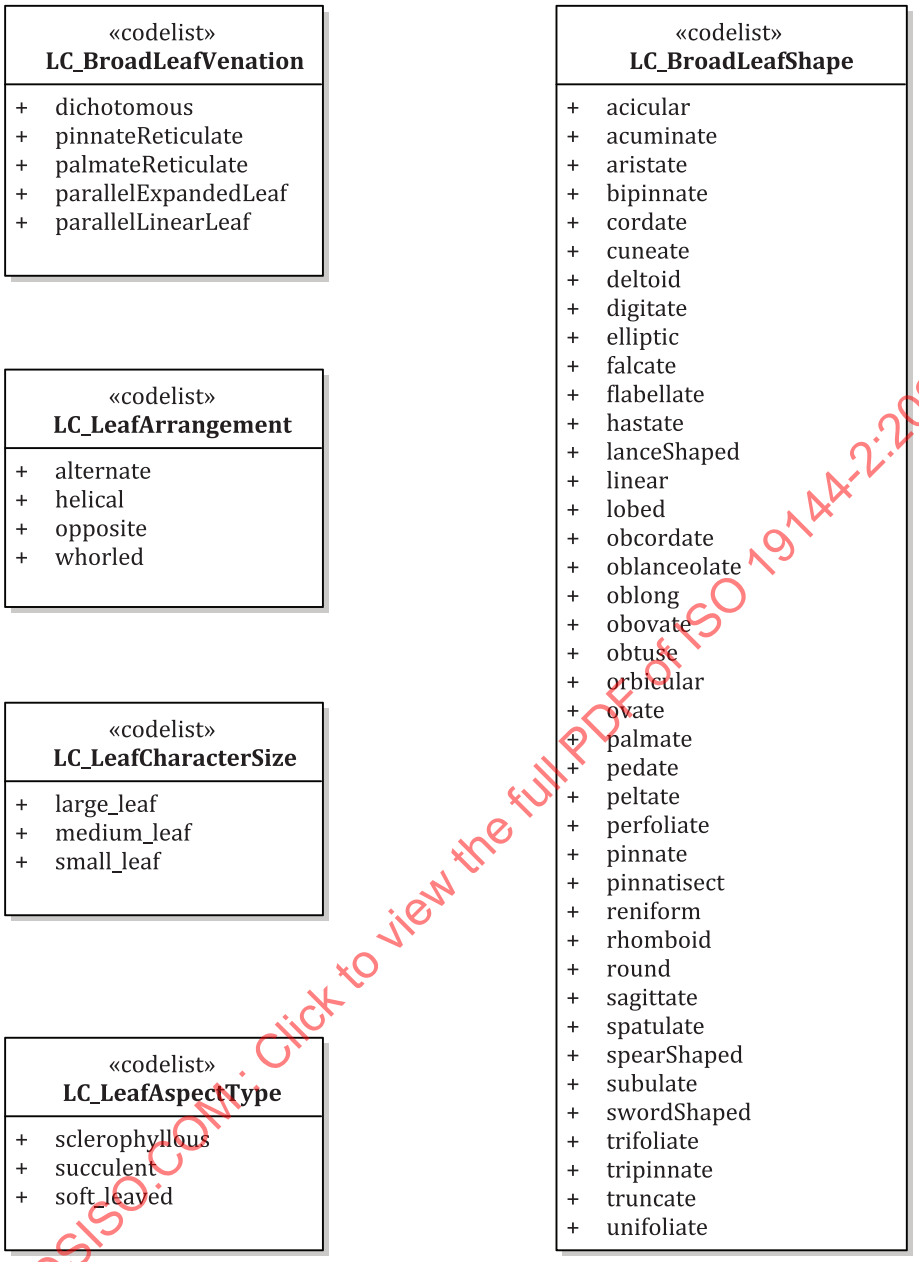


Figure 12 — Code lists that support the LC_WoodyGrowthForm object structure

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

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

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.

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.

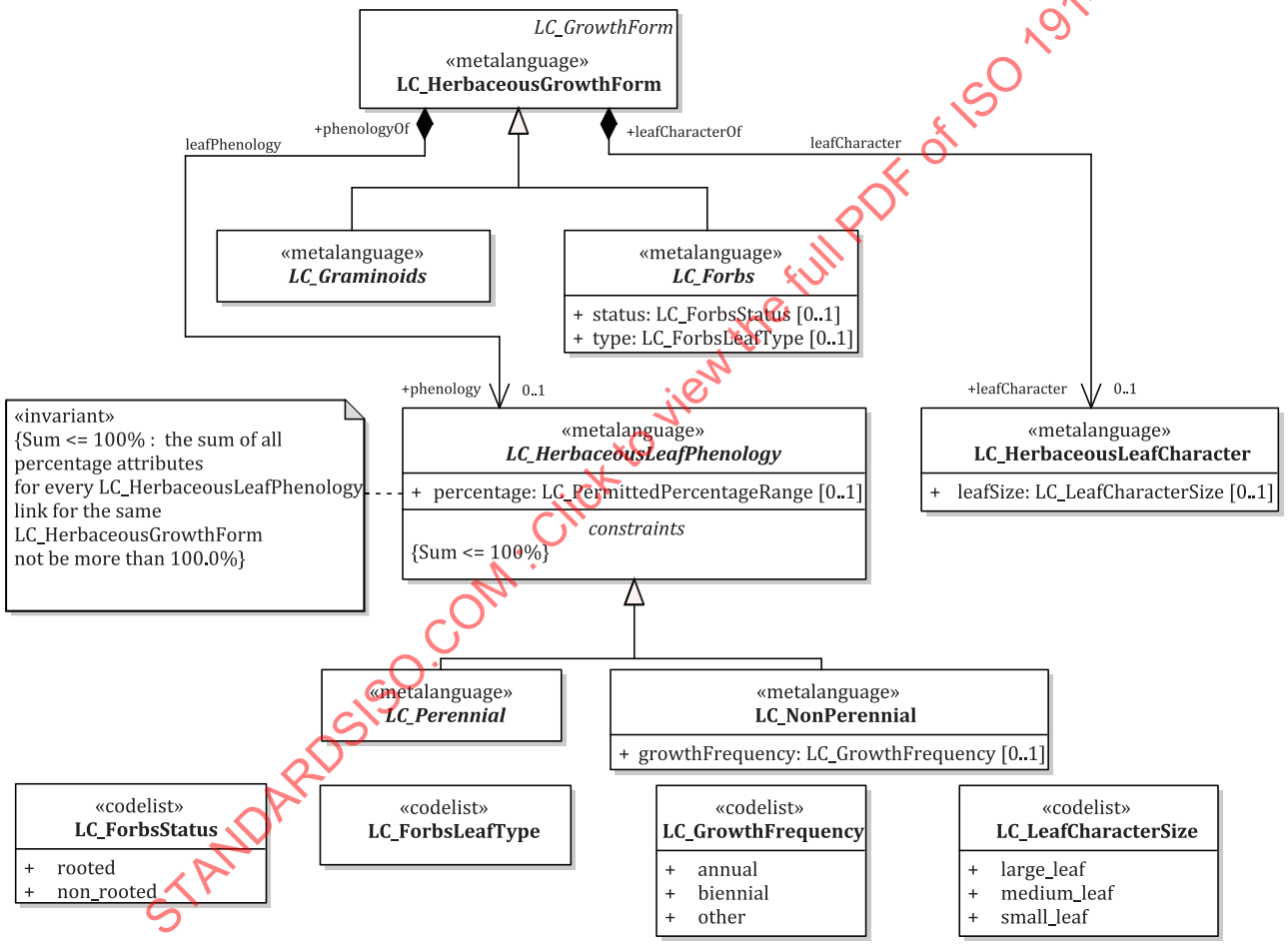


Figure 13 — Subtypes of LC_HerbaeceousGrowthForm

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.

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.

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.

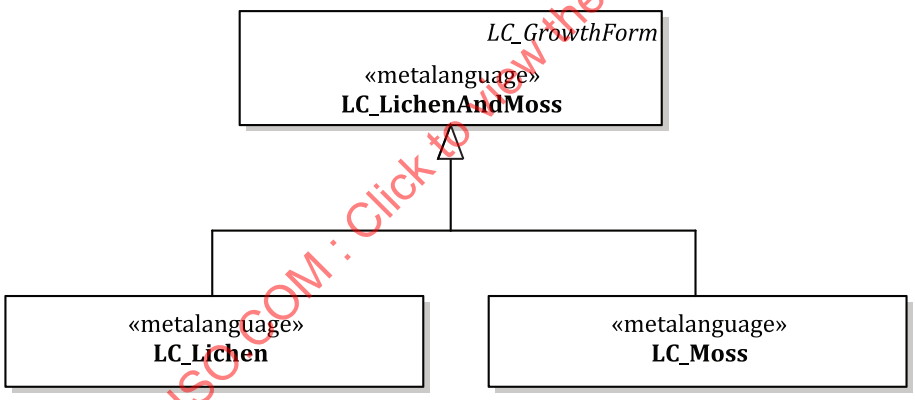


Figure 14 — Subtypes of LC_LichenAndMoss

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.

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.

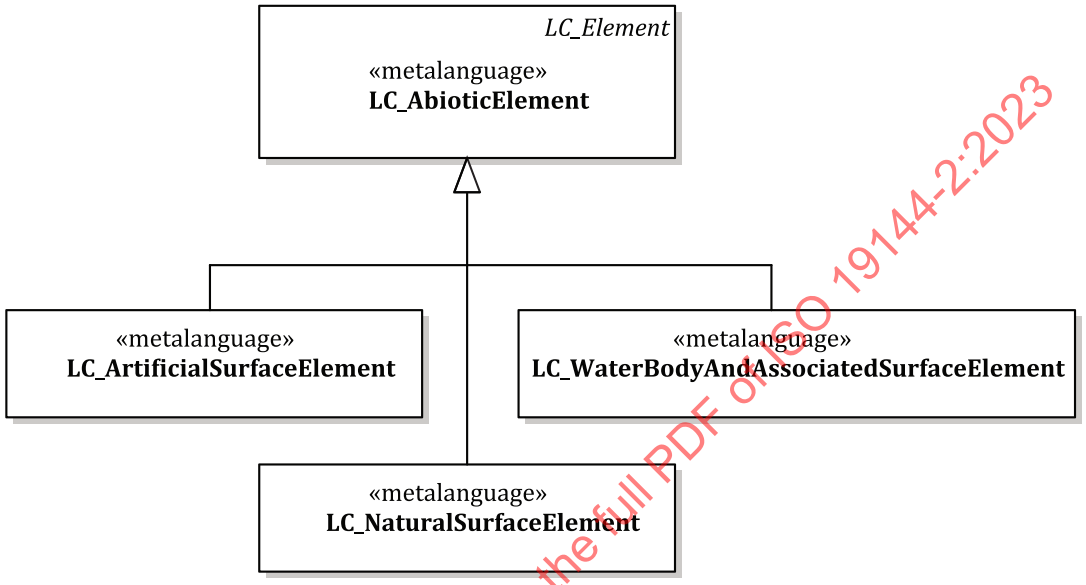


Figure 15 — Subtypes of LC_AbioticElement

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.

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.

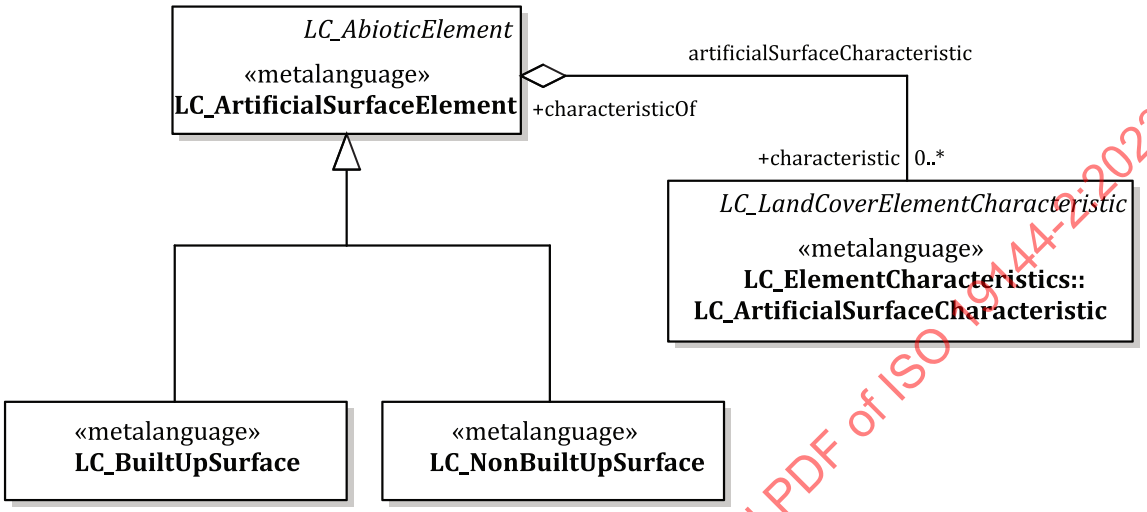


Figure 16 — Subtypes of LC_ArtificialSurfaceElement

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.

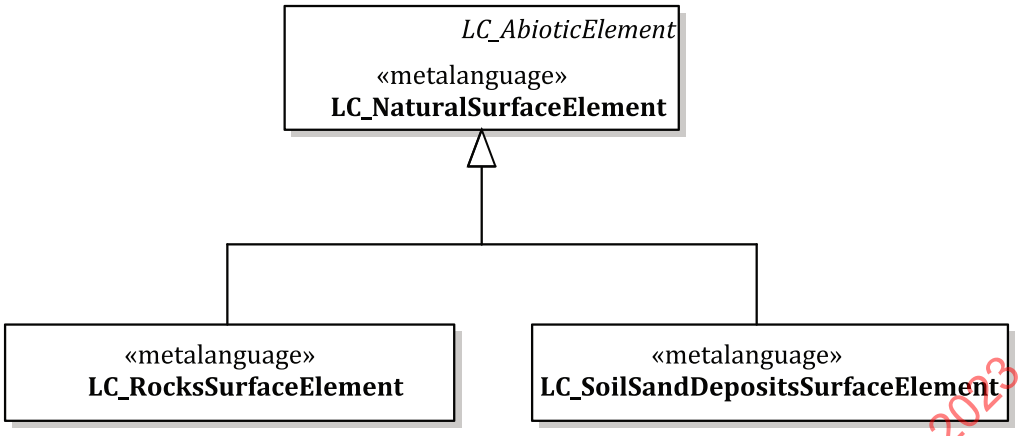


Figure 17 — Subtypes of LC_NaturalSurfaceElement

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.

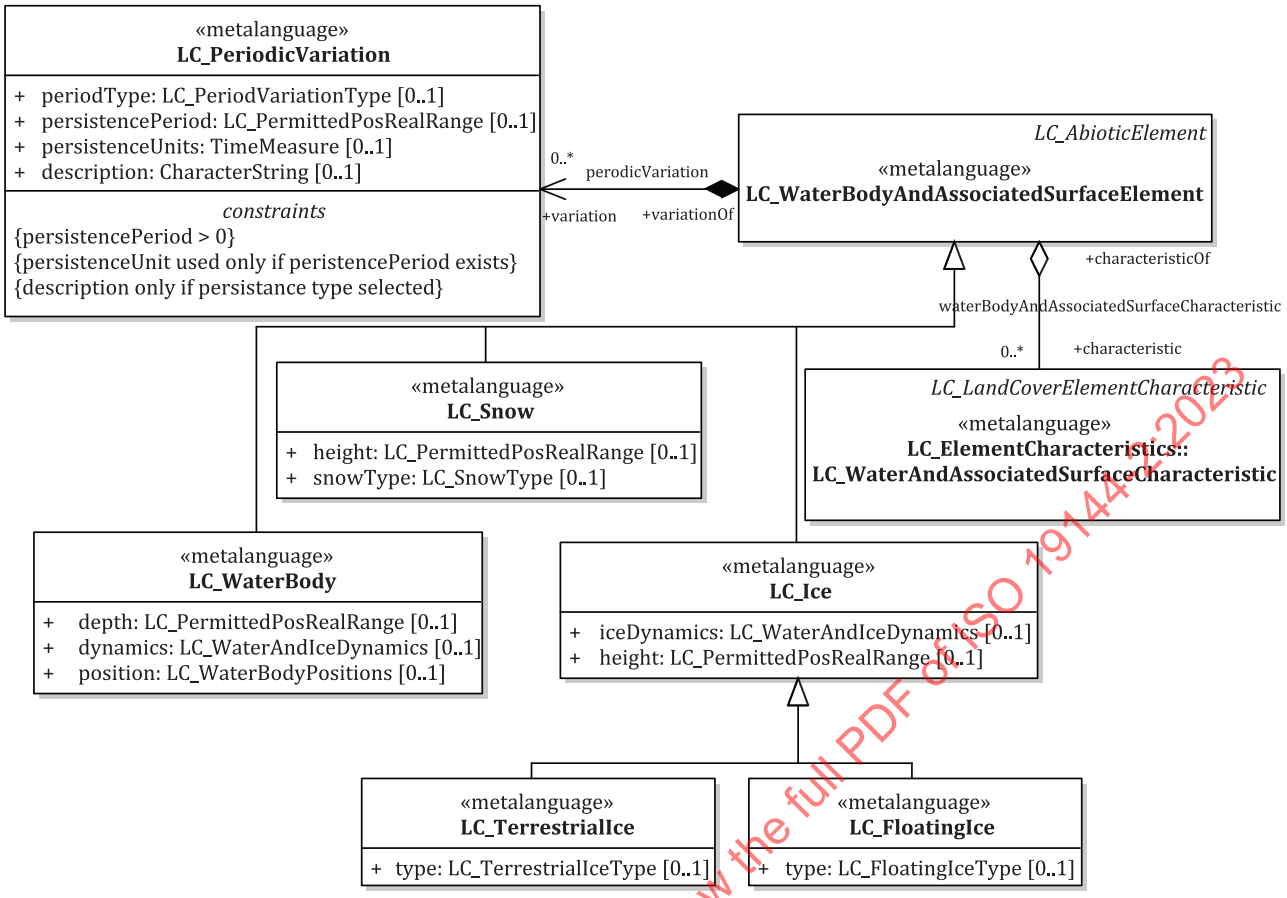


Figure 18 — Subtypes of LC_WaterBodyAndAssociatedSurfaces

The code lists that support LC_ WaterBodyAndAssociatedSurfaces are shown in Figure 19.

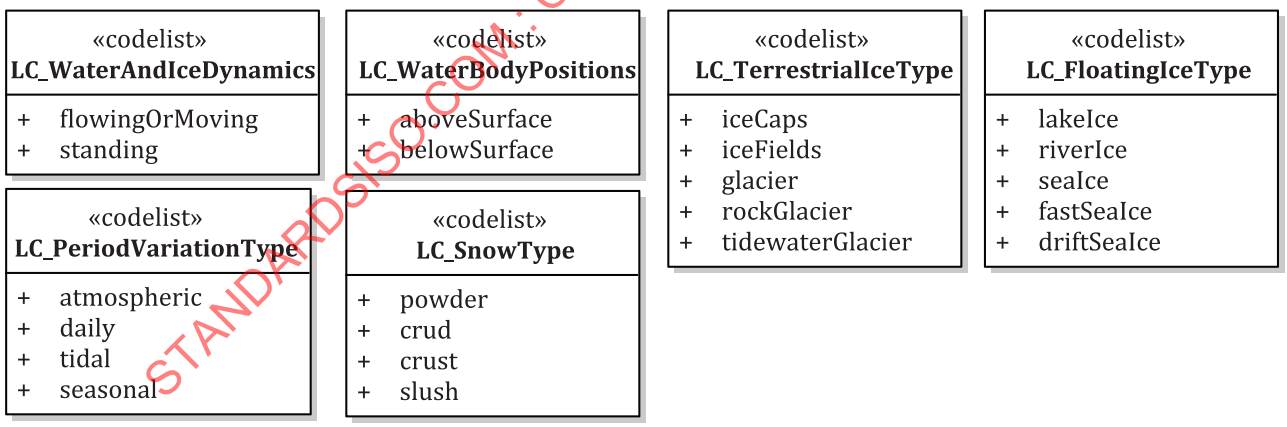


Figure 19 — Code lists that support the LC_WaterBodyAndAssociatedSurfaces object structure

8.16.2 LC_WaterBodyAndAssociatedSurfaceElement classes

8.16.2.1 LC_WaterBody

The LC_WaterBody metalanguage object is a subtype of LC_WaterBodyAndAssociatedSurfaceElement. It has three optional attributes: *depth*, *dynamics* and *position*. The permitted values of the attribute *depth* are described by the value object LC_PermittedPosRealRange. Depth is negative to height. The permitted values of the optional attribute *dynamics* are described by the enumerated value object

LC_WaterAndIceDynamics. The permitted values of the optional attribute *position* are described by the enumerated value object LC_WaterBodyPositions. Other attributes can be established through registration. It has a relationship to the component LC_PeriodicVariation. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all consolidated water bodies.

8.16.2.2 LC_Snow

The LC_Snow metalanguage object is a subtype of LC_WaterBodyAndAssociatedSurfaceElement. It has two attributes: *height* and *snowType*. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealRange. The permitted values of the attribute *snowType* are described by the value object LC_SnowType. Other attributes can be established through registration. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all snow-covered areas.

8.16.2.3 LC_Ice

The LC_Ice metalanguage object is a subtype of LC_WaterBodyAndAssociatedSurfaceElement. It has two attributes: *dynamics* and *height*. The permitted value of the attribute *dynamics* is described by the enumerated value object LC_WaterAndIceDynamics. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealRange. Other attributes can be established through registration. It has two subtypes: LC_TerrestrialIce and LC_FloatingIce. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for all ice-covered areas.

8.16.2.4 LC_TerrestrialIce

The LC_TerrestrialIce metalanguage object is a subtype of LC_Ice. It has one attribute *type*. The permitted values of the attribute *type* are described by the value object LC_terrestrialIceType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for terrestrial areas covered with ice.

8.16.2.5 LC_FloatingIce

The LC_FloatingIce metalanguage object is a subtype of LC_Ice. It has one attribute *type*. The permitted values of the attribute *type* are described by the value object LC_floatingIceType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for water bodies covered with floating ice.

8.16.2.6 LC_WaterAndIceDynamics

The code list LC_WaterAndIceDynamics contains a list of water body and ice dynamic types. This list contains two types:

— flowing: flowing or moving;

— standing: standing (still not moving).

This list can be extended through registration.

8.16.2.7 LC_WaterBodyPositions

The code list LC_WaterBodyPositions contains a list of water body position status types. This list contains two types:

— aboveSurface: water element is above surface;

— belowSurface: water element is below surface.

This list can be extended through registration.

8.16.2.8 LC_PeriodicVariation

The LC_PeriodicVariation component is related to the LC_WaterBodyAndAssociatedSurfaceElement metalanguage object by the relationship *periodicVariation*. It has four optional attributes: *periodType*, *persistencePeriod*, *persistenceUnits* and *description*. The attribute *periodType* describes the type of variation by use of the code list LC_PeriodVariationType. The attribute *persistencePeriod* describes the persistence period as a time duration. A constraint exists requiring that *persistencePeriod* always be greater than 0. The attribute *persistenceUnits* describes the time units used for the persistence period using the *TimeMeasure* interface class. *TimeMeasure* is defined in ISO 19103 as a basic measurement type. A constraint exists requiring that persistence units be used if and only if a persistence period exists. The attribute *description* provides an optional textual characterization of the persistence types. A constraint exists requiring that a description exist only if a persistence type from the code list has been chosen. The component LC_PeriodicVariation can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElement to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.16.2.9 LC_PeriodicVariationType

The code list LC_PeriodicVariationType contains a list of types of periodic variations. This list contains four types:

— atmospheric: varying with atmospheric pressure;

— daily: varying daily;

— tidal: varying with the tides;

— seasonal: varying with the seasons.

This list can be extended through registration.

8.16.2.10 LC_SnowType

The code list LC_SnowType contains a list of types of snow. This list contains four types:

— powder: uncompacted, low density, low moisture snow (normally freshly fallen);

— crud: uneven compacting of powder snow leading to uneven ridges and formation of iced areas on the snow surface;

— crust: a layer of snow on the surface of the snowpack that is stronger than the snow below, which can be powder snow;

— slush: partially melted snow which forms an icy consistency with liquid water forming into pools.

This list can be extended through registration.

8.16.2.11 LC_FloatingIceType

The code list LC_FloatingIce contains a list of types of floating ice. This list contains five types:

— lakeIce: ice on a lake;

— riverIce: ice on a river;

— seaIce: ice at sea (exclusive of fastSeaIce and driftSeaIce);

— fastSeaIce: sea ice that has frozen along coast or the sea floor and extends out from land into sea;

— driftSeaIce: sea ice that floats on the surface.

This list can be extended through registration.

8.16.2.12 LC_TerrestrialIceType

The code list LC_TerrestrialIceType contains a list of types of terrestrial ice. This list contains five types:

— iceCaps: ice dome or cap – although not specifically associated with a specific geographic feature, the domes of ice caps are normally centred around the highest point or mountain peak, with ice flowing away from the highest point;

— iceFields: extensive areas of interconnected valley glaciers;

— glacier: a large, slow-moving river of ice, formed from compacted layers of snow. Different types of glacier include Valley, Mountain and outline. The movement is in response to gravity and high pressure;

— rockGlacier: glacier formed of blocky detritus (such as rocks) and ice which are formed outward and downslope of structures such as glaciers;

— tidewaterGlacier: glaciers that flow into the sea. pieces may break off and form icebergs.

This list can be extended through registration.

8.16.2.13 LC_WaterAndAssociatedSurfacesCharacteristic

The LC_WaterAndAssociatedSurfacesCharacteristic metalanguage object is a component related to the LC_WaterBodyAndAssociatedSurfaceElement metalanguage object by the aggregation relation *waterBodyAndAssociatedSurfaceCharacteristic*. The component LC_WaterAndAssociatedSurfacesCharacteristic can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElement to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.17 LC_BuiltUpSurface

8.17.1 LC_BuiltUpSurface subtypes

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 artificial surfaces. The LC_BuiltUpSurface metalanguage object has two subtypes: LC_LinearSurface and LC_NonLinearSurface.

The permitted values of the optional attribute constructionMaterial are described by the code list LC_ConstructionMaterial. This is represented in Figure 20.

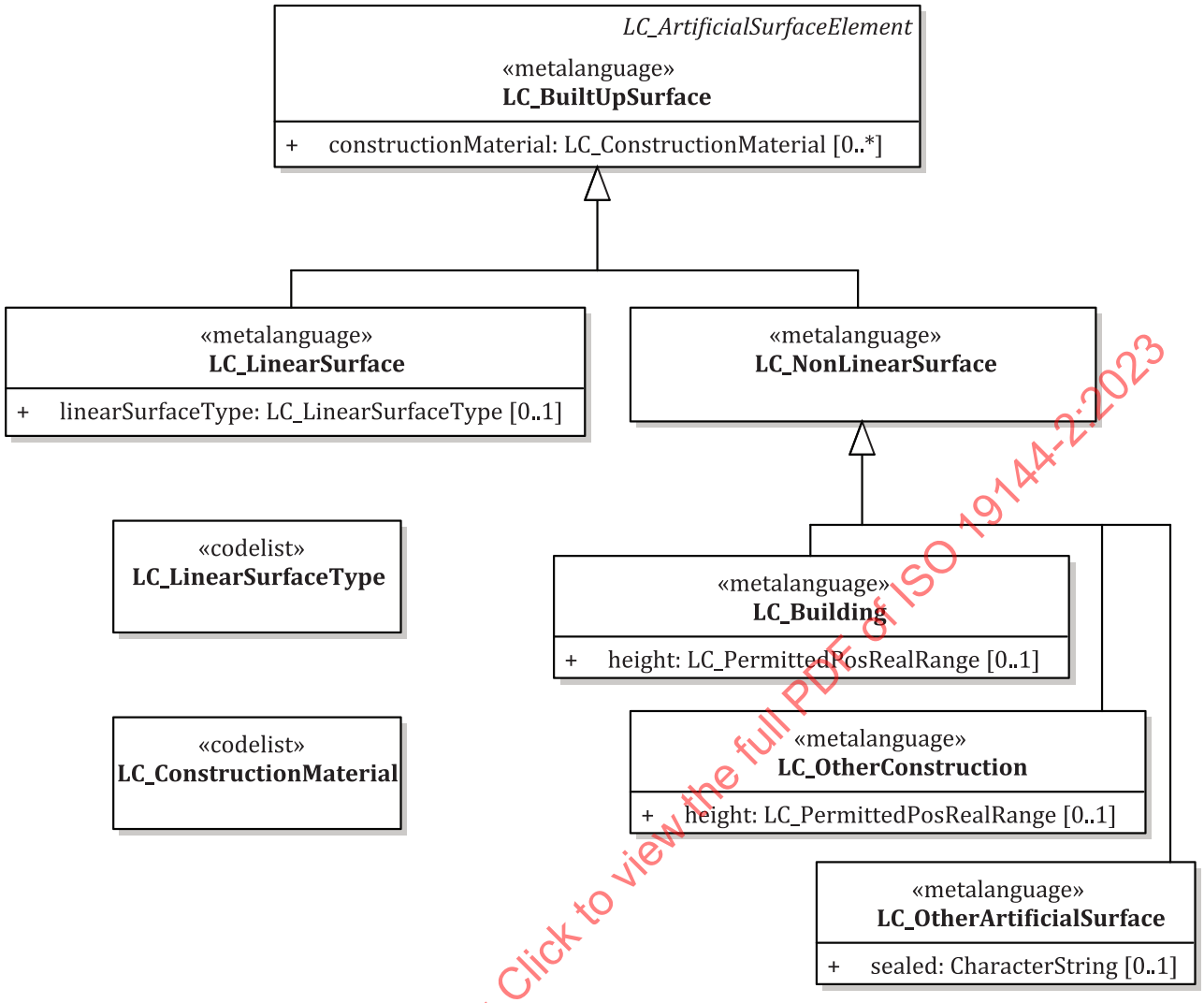


Figure 20 — Subtypes of LC_BuiltUpSurface

8.17.2 LC_BuiltUpSurface classes

8.17.2.1 LC_LinearSurface

The LC_LinearSurface metalanguage object is a subtype of LC_BuiltUpSurface. The permitted values of the optional attribute *type* are described by the code list LC_LinearSurfaceType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all built-up linear artificial surfaces.

NOTE Common types of linear surfaces are roads, railways, communication or power line corridoors. These linear surface objects do not describe Land Use. They are names for the physical Land Cover that corresponds to a road, railway, communication or other system. It is simpler and more widely understood to say “railway” than “two iron rails on a gravel, concrete or other support material. However, the term “railway” in a Land Cover context does not mean that this object is used as a transportation system for trains. A Land-Use-related name can be used to identify a particular physiognomic appearance of an artificial Land Cover. The “use aspect” of a road, a railway, a communication and other linear feature can be described as a characteristic associated with these classes (see ISO/TS 19144-3). The enumeration associated with the attribute *linearSurfaceType* is restricted to purely physiognomic aspects.

8.17.2.2 LC_NonLinearSurface

The LC_NonLinearSurface metalanguage object is a subtype of LC_BuiltUpSurface. It has three subtypes: LC_Building, LC_OtherConstruction and LC_OtherArtificialSurface. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all nonlinear built-up artificial surfaces.

8.17.2.3 LC_Building

The LC_Building metalanguage object is a subtype of LC_NonLinearSurface. It has the attribute *height*. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealRange. The percentage cover of the building within the area described by that element can be described by the attribute *cover* in the class LC_ElementHorizontalArrangement which is a component of LC_Element of which LC_Building is a subtype. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class, in a Land Cover classification system, for land covered by building or structure that has the physiognomic appearance of a building.

NOTE A building can be of a non-rectangular shape and only cover a portion of the geometric area identified for the element.

8.17.2.4 LC_OtherConstruction

The LC_OtherConstruction metalanguage object is a subtype of LC_NonLinearSurface. It has the attribute *height*. The permitted values of the attribute *height* are described by the value object LC_PermittedRealRange. The percentage cover of the other construction within the area described by that element can be described by the attribute *cover* in the class LC_ElementHorizontalArrangement which is a component of LC_Element of which LC_OtherConstruction is a subtype. This is similar to the use of the attribute *cover* in LC_Building in 8.17.2.3. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class, in a Land Cover classification system, for land covered by construction that has the physiognomic appearance of other than a building.

NOTE A construction can only cover a portion of the geometric area identified for the element.

8.17.2.5 LC_OtherArtificialSurface

The LC_OtherArtificialSurface metalanguage object is a subtype of LC_NonLinearSurface. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class, in a Land Cover classification system, for land covered by another artificial surface. It has the optional attribute *sealed* which indicates whether the surface is porous and will allow for the absorption of surface water.

8.17.2.6 LC_LinearSurfaceType

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

8.17.2.7 LC_ConstructionMaterial

The code list LC_ConstructionMaterial contains a list of hardness states for construction materials. At the metalanguage level this list is empty, but it can be populated through registration.

8.18 LC_NonBuiltUpSurface

8.18.1 LC_NonBuiltUpSurface subtypes

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 artificial surfaces. The LC_NonBuiltUpSurface

metalanguage object has two subtypes: LC_DumpSite and LC_Extraction. This is represented in Figure 21.

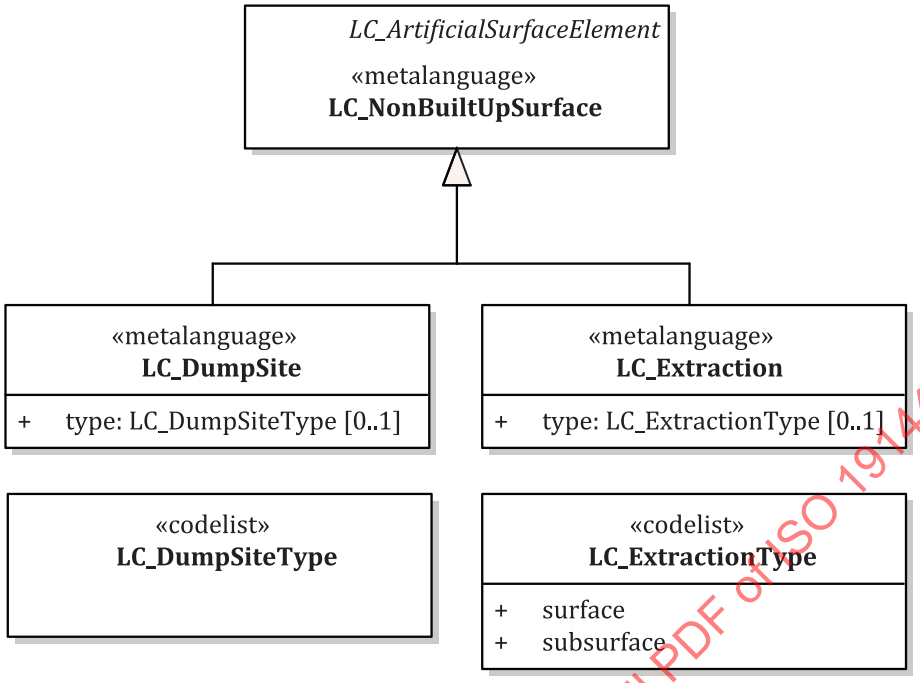


Figure 21 — Subtypes of LC_NonBuiltUpSurface

8.18.2 LC_NonBuiltUpSurface classes

8.18.2.1 LC_DumpSite

The LC_DumpSite metalanguage object is a subtype of LC_NonBuiltUpSurface. The permitted values of the optional attribute *type* are described by the code list LC_DumpSiteType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all deposit non-built-up artificial surfaces. The detailed kind of material being dumped is considered as Land Use.

8.18.2.2 LC_Extraction

The LC_Extraction metalanguage object is a subtype of LC_NonBuiltUpSurface. It has one attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_ExtractionType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for all extraction non-built-up artificial surfaces. The detailed kind of material being extracted is considered as Land Use.

8.18.2.3 LC_DumpSiteType

The code list LC_DumpSiteType contains a list of types of dump sites or areas where different types of material are dumped for an artificial non-built-up artificial surface. At the metalanguage level this list is empty, but it can be populated through registration.

8.18.2.4 LC_ExtractionType

The code list LC_ExtractionType contains a list of types of extraction for an artificial non-built-up artificial surface. This list contains two types:

— surface: top layer of the ground;

— subsurface: below the surface.

This list can be extended through registration.

8.19 LC_RocksSurfaceElement

8.19.1 LC_RocksSurface subtypes

The LC_RocksSurface 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 consolidated natural surfaces. It has two subtypes: LC_BareRock and LC_Hardpan. This is represented in Figure 22.

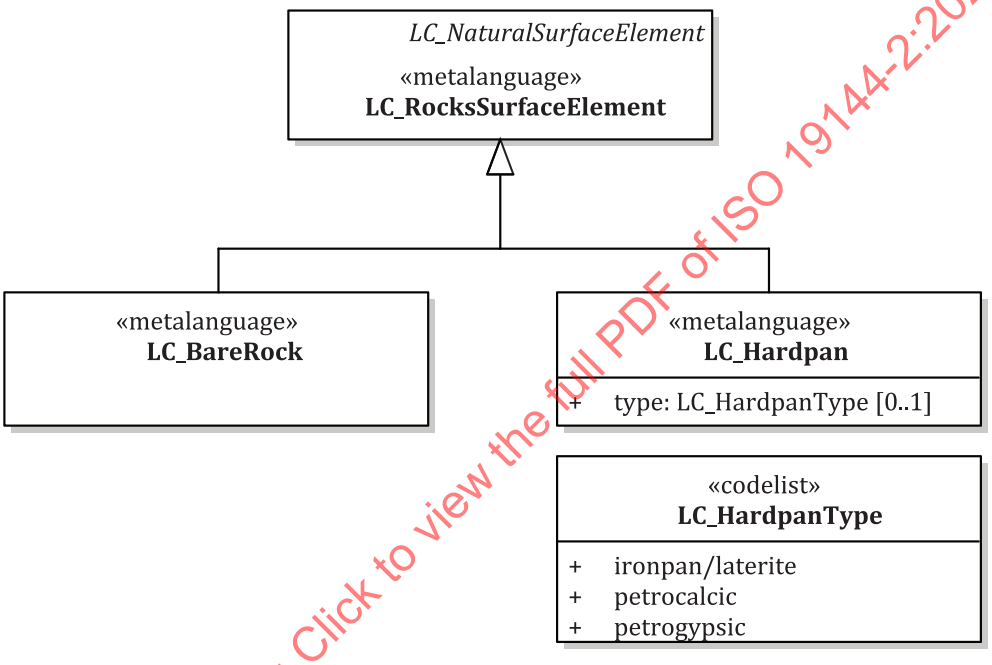


Figure 22 — Subtypes of LC_RocksSurfaceElement

8.19.2 LC_RocksSurfaceElement classes

8.19.2.1 LC_BareRock

The LC_BareRock metalanguage object is a subtype of LC_RocksSurfaceElement. It has one optional attribute: *cover*. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for a bare rock natural surface.

8.19.2.2 LC_Hardpan

The LC_Hardpan metalanguage object is a subtype of LC_RocksSurfaceElement. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_HardpanType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for a hardpan natural surface.

8.19.2.3 LC_HardpanType

The code list LC_HardpanType contains a list of hardpan types. This list contains three types:

— ironpan/laterite: metaferricrete – iron oxide-based hardpan;

— petrocalcic: calcium carbonate-based hardpan;

— petrogypsic: gypsum-based hardpan.

This list can be extended through registration.

8.20 LC_SoilSandDepositsSurfaceElement

8.20.1 LC_SoilSandDepositsSurfaceElement subtypes

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 specific types of natural surfaces. It has four subtypes: LC_CoarseMineralFragments, LC_BareSoil, LC_LooseAndShiftingSand and LC_Deposits. This is represented in Figure 23.

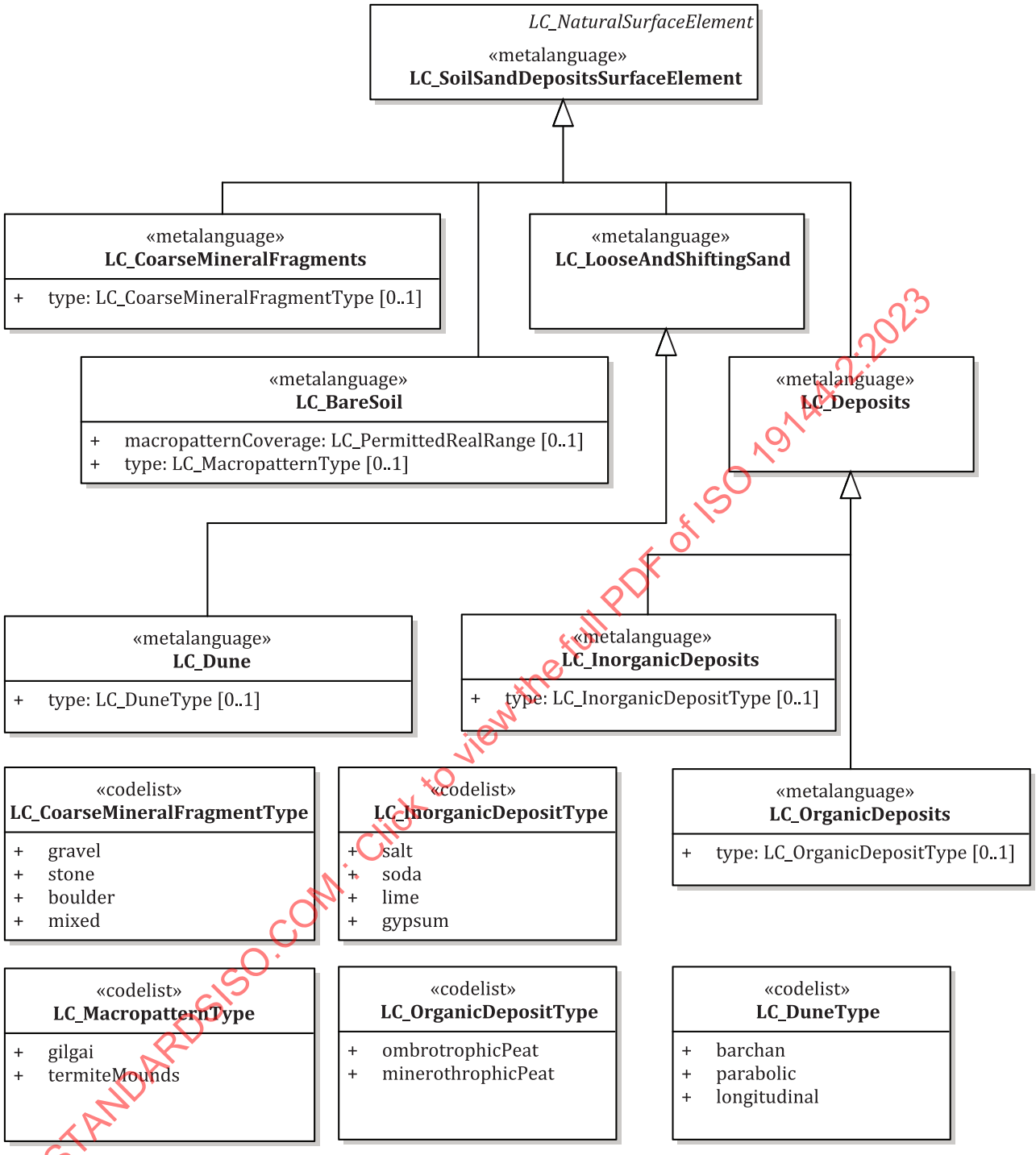


Figure 23 — Subtypes of LC_SoilSandDepositsSurfaceElement

8.20.2 LC_SoilSandDepositsSurfaceElement classes

8.20.2.1 LC_CoarseMineralFragments

The LC_CoarseMineralFragments metalanguage object is a subtype of LC_SoilSandDepositsSurfaceElement. It has the attribute *type*. The permitted values of the attribute *type* are described by the code list LC_CoarseMineralFragmentType. The percentage cover of the coarse mineral fragments within the area described by that element can be described by the attribute *cover* in the class LC_ElementHorizontalArrangement which is a component of LC_Element of which LC_CoarseMineralFragments is a subtype. This metalanguage object, when instantiated, allows the

generation of a Land Cover feature class in a Land Cover classification system for a coarse fragment consolidated natural surface.

8.20.2.2 LC_BareSoil

The LC_BareSoil metalanguage object is a subtype of LC_SoilSandDepositsSurfaceElement. It has two optional attributes: *macropatternCoverage* and *type*. The permitted values of the optional attribute *macropatternCoverage* are described by the value object LC_PermittedPercentageRange. The permitted values of the attribute *type* are described by the code list LC_MacropatternType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for a bare soil natural surface.

8.20.2.3 LC_LooseAndShiftingSand

The LC_LooseAndShiftingSand metalanguage object is a subtype of LC_SoilSandDepositsSurfaceElement. It has one subtype: LC_Dune. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for a loose and shifting sand natural surface. It has one subtype: LC_Dune.

8.20.2.4 LC_Deposits

The LC_Deposits metalanguage object is a subtype of LC_SoilSandDepositsSurfaceElement. It has two subtypes: LC_OrganicDeposits and LC_InorganicDeposits. This metalanguage object, when instantiated, allows the generation of a general Land Cover feature class in a Land Cover classification system for a deposits natural surface.

8.20.2.5 LC_Dune

The LC_Dune metalanguage object is a subtype of LC_LooseAndShiftingSand. It has the optional attribute *type*. The permitted values of the attribute *type* are described by the code list LC_DuneType. The percentage cover of dune within the area described by that element can be described by the attribute *cover* in the class LC_ElementHorizontalArrangement which is a component of LC_Element of which LC_Dune is a subtype. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for a sand dune soil and sand deposit.

8.20.2.6 LC_OrganicDeposits

The LC_OrganicDeposits metalanguage object is a subtype of LC_Deposits. It has one attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_OrganicDepositType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for an organic soil and sand deposit.

8.20.2.7 LC_InorganicDeposits

The LC_InorganicDeposits metalanguage object is a subtype of LC_Deposits. It has one attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_InorganicDepositType. This metalanguage object, when instantiated, allows the generation of a Land Cover feature class in a Land Cover classification system for an inorganic soil and sand deposit.

8.20.2.8 LC_CoarseMineralFragmentType

The code list LC_CoarseMineralFragmentType contains a list of fragment types. This list contains four types:

— gravel: loose aggregation of small mineral fragments;

— stone: aggregation of small and medium mineral fragments;

— boulder: aggregation of large mineral fragments;

— mixed: mixed coarse mineral fragment types.

This list can be extended through registration.

8.20.2.9 LC_MacropatternType

The code list LC_MacropatternType contains a list of macropattern types. This list contains two types:

— gilgai: succession of enclosed micro-basins and micro-heaps in nearly level areas or of micro-valleys and micro-ridges that run parallel to the direction of the slope;

— termiteMounds: cone-shaped hills of hardened earth up to several metres high built by termite insects. The termite mounds can be built around tree trunks or poles.

NOTE 1 The two types have been included because they are the most common features in many parts of the world (e.g. Africa, South America, etc.).

NOTE 2 Gilgai are the micro-relief typical of Vertisols, which expand and contract largely with distinct seasonal changes in moisture content.

This list can be extended through registration.

8.20.2.10 LC_DuneType

The code list LC_DuneType contains a list of dune types. This list contains three types:

— barchan: crescent-shaped dune produced by the action of wind;

— parabolic: parabolic shaped dunes that have arms that point upwind;

— longitudinal: linear shaped dune elongated parallel to the prevailing wind.

This list can be extended through registration.

8.20.2.11 LC_InorganicDepositType

The code list LC_InorganicDepositType contains a list of types of inorganic deposits. This list contains four types:

— salt: deposit of salt;

— soda: deposit of mineral soda;

— lime: deposit of lime;

— gypsum: deposit of gypsum.

This list can be extended through registration.

8.20.2.12 LC_OrganicDepositType

The code list LC_OrganicDepositType contains a list of types of organic deposits. This list contains two types:

— ombrothrophicPeat: peatland supplied by water from rain and snow;

— minerothrophicPeat: peatland supplied by water carrying minerals form surrounding soil.

This list can be extended through registration.

NOTE The types of peat can be described by the code list LC_PeatType.

8.21 LC_ClassCharacteristic

8.21.1 LC_ClassCharacteristic subtypes

Additional information can be provided to further refine metalanguage objects within the LCML by the use of Characteristics. A classification class characteristic is a component aggregated to an entire LC_LandCoverClassDescriptor metalanguage object. An LC_LandCoverClassDescriptor metalanguage object is instantiated to a Legend Class within a Land Cover classification system and so the ClassCharacteristic is additional information to refine an entire class. The use of characteristics in the LCML is optional.

These class characteristic subtypes apply for a whole class because they relate to the all elements in one or more strata defining a specific class.

The component LC_ClassCharacteristic is related to LC_LandCoverClassDescriptor by the relation characteristic. It has five subtypes: LC_ClimateCharacteristic, LC_LandFormCharacteristic, LC_GeographicalAspectsCharacteristic, LC_TopographicalAspectsCharacteristic and LC_SurfaceCharacteristic. This is represented in Figure 24.

The code lists that support LC_ClassCharacteristic are shown in Figure 25.

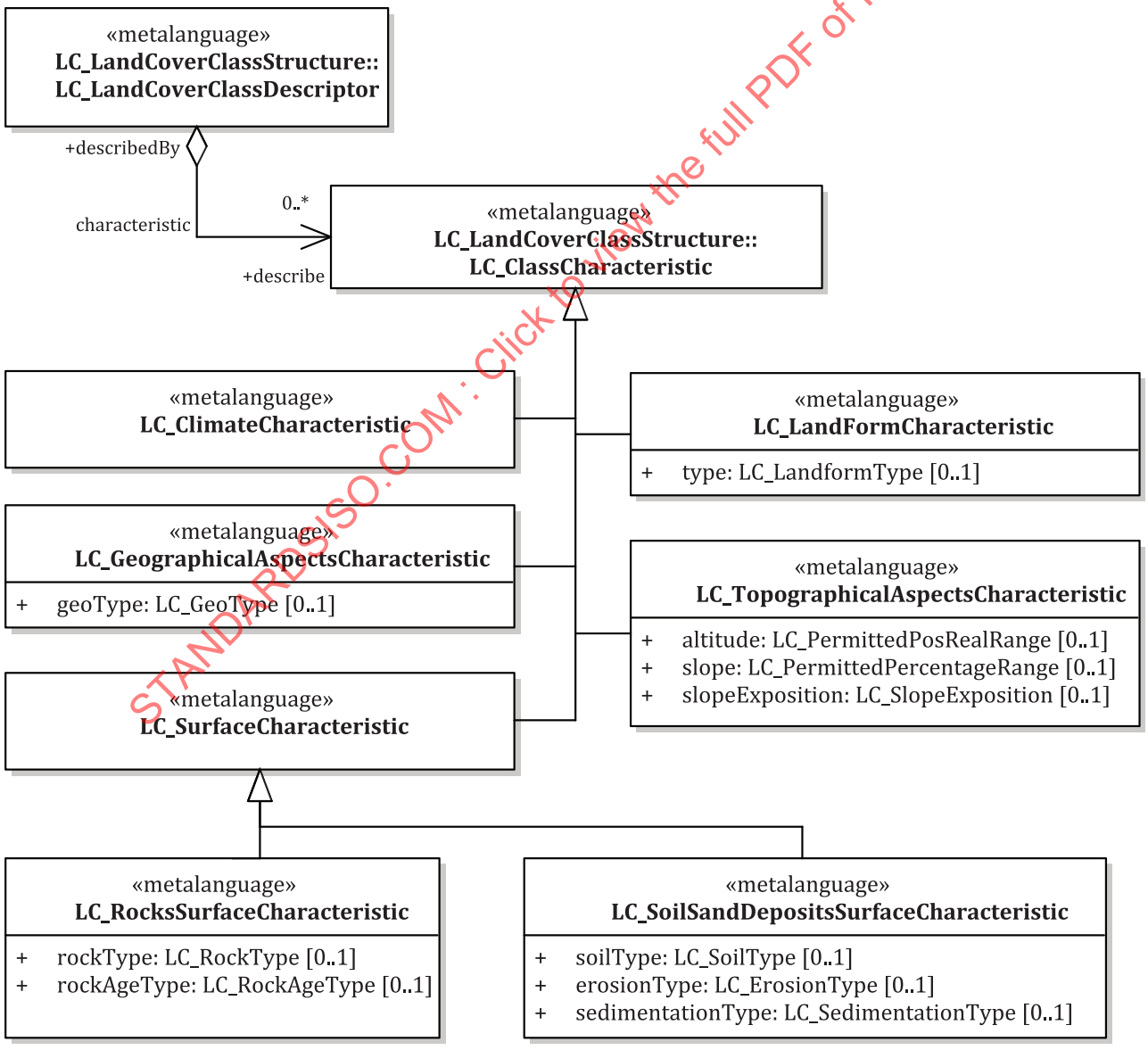


Figure 24 — Subtypes of LC_ClassCharacteristic

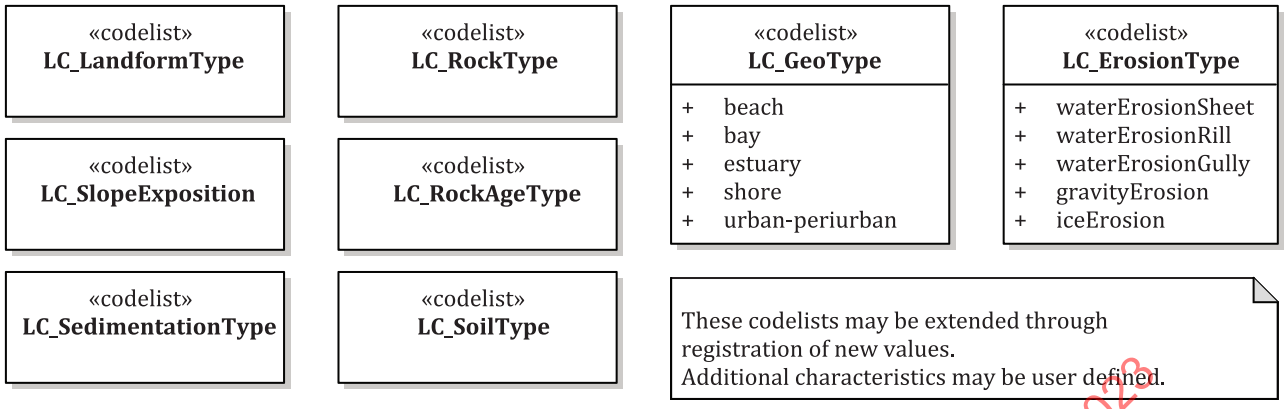


Figure 25 — Code lists that support the LC_ClassCharacteristic object structure

8.21.2 LC_ClassCharacteristic classes

8.21.2.1 LC_ClimateCharacteristic

The LC_ClimateCharacteristic component is a subtype of LC_ClassCharacteristic. Climate is the state, including a statistical description, of the climate system. The different methods of describing climate are user-defined. At the metalanguage level this list is empty, but it may be populated through registration. This component can be used to refine the LC_LandCoverClassDescriptor metalanguage object corresponding to an entire LC_LandCoverClass with respect to climate to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.21.2.2 LC_LandFormCharacteristic

The LC_LandFormCharacteristic component is a subtype of LC_ClassCharacteristic. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_LandFormType. This component can be used to refine the LC_LandCoverClassDescriptor metalanguage object corresponding to an entire LC_LandCoverClass with respect to land form to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.21.2.3 LC_GeographicalAspectsCharacteristic

The LC_GeographicalAspectsCharacteristic component is a subtype of LC_ClassCharacteristic. It has one optional attribute: *geoType*. The permitted values of the attribute *geoType* are described by the code list LC_GeoType. This component can be used to refine the metalanguage object corresponding to an entire LC_LandCover class with respect to the geographic aspect to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. The LC_GeographicAspect component describes the characteristics of a particular classification class that have a well-known geographic type that is not Land Cover specific.

8.21.2.4 LC_TopographicalAspectsCharacteristic

The LC_TopographicalAspectsCharacteristic component is a subtype of LC_ClassCharacteristic. It has three optional attributes: *altitude*, *slope* and *slopeExposition*. The permitted values of the attribute *altitude* are described by the value object LC_PermittedRealRange. The permitted values of the attribute *slope* are described by the value object LC_PermittedPercentageRange. The absence of the attribute slope indicates that the value is unknown. To specify a flat surface the slope can be specified as 0. The permitted values of the attribute *slopeExposition* are described by the code list LC_SlopeExposition. This component can be used to refine the LC_LandCoverClassDescriptor metalanguage object corresponding to an entire LC_LandCoverClass with respect to topographical aspects to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.21.2.5 LC_SurfaceCharacteristic

The LC_SurfaceCharacteristic component is a subtype of LC_ClassCharacteristic. It has two subtypes: LC_RocksCharacteristic and LC_SoilSandDepositsSurfaceCharacteristic.

8.21.2.6 LC_RocksSurfaceCharacteristic

The LC_RocksSurfaceCharacteristic metalanguage object is a subtype of LC_SurfaceCharacteristic. It has two optional attributes: *rockType* and *rockAgeType*. The permitted values of the attribute *rockType* are described by the code list LC_RockType. The permitted values of the attribute *rockAgeType* are described by the code list LC_RockAgeType. This component can be used to refine the LC_LandCoverClassDescriptor metalanguage object corresponding to an entire LC_LandCoverClass with respect to rocks and hardpan surface characteristics to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.21.2.7 LC_SoilSandDepositsSurfaceCharacteristic

The LC_SoilSandDepositsSurfaceCharacteristic metalanguage object is a subtype of LC_SurfaceCharacteristic. It has three optional attributes: *soilType*, *erosionType* and *sedimentationType*. The permitted values of the attribute *soilType* are described by the code list LC_SoilType. The permitted values of the attribute *erosionType* are described by the code list LC_ErosionType. The permitted values of the attribute *sedimentationType* are described by the code list LC_SedimentationType. This component can be used to refine the LC_LandCoverClassDescriptor metalanguage object corresponding to an entire LC_LandCoverClass with respect to unconsolidated surface characteristics to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.21.2.8 LC_LandformType

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

8.21.2.9 LC_GeoType

The code list LC_GeoType contains a list of characteristics. This list contains five types:

— beach: shore of a sea, lake or a river;

— bay: broad indentation in a coastline;

— estuary: mouth of a river, where the tide meets the stream;

— shore: the land bordering on the sea, lake or a river;

— urban-periurban: within or around an urban area.

This list can be extended through registration.

8.21.2.10 LC_SlopeExposition

The code list LC_SlopeExposition contains a description of the direction of exposition of a slope such as “North”, “South”, “East” or “West”. At the metalanguage level this list is empty, but it can be populated through registration.

8.21.2.11 LC_RockType

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

8.21.2.12 LC_RockAgeType

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

8.21.2.13 LC_SoilType

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

8.21.2.14 LC_ErosionType

The code list LC_ErosionType contains a list of erosion types. This list contains five types:

— waterErosionSheet: erosion resulting from the uniform removal of soil in thin layers;

— waterErosionRill: erosion resulting from the concentration of surface water into deeper, faster-flowing channels;

— waterErosionGully: erosion which occurs when water is channelled across unprotected land and washes away the soil along the drainage lines;

— gravityErosion: the transfer of rock and soil down-slope by direct action of gravity without a flowing medium;

— iceErosion: erosion resulting from the movement of ice, such as glaciers.

This list can be extended through registration.

8.21.2.15 LC_SedimentationType

The code list LC_SedimentationType contains a list of sedimentation types. Examples of such types are water sediment and wind sediment. At the metalanguage level this list is empty, but it can be populated through registration.

8.22 LC_LandCoverElementCharacteristic

8.22.1 LC_LandCoverElementCharacteristic subtypes

Additional information can be provided to further refine the individual elements that are assembled to generate an LC_LandCoverClassDescriptor metalanguage object within the LCML by the use of Element Characteristics. An element characteristic is distinct from a classification class characteristic in that it applies to a specific LC_Element. Element characteristics can be applied to specific elements or there can be general elements defined related to the generic UML class LC_Element. The use of characteristics in the LCML is optional.

The component LC_LandCoverElementCharacteristic is related to LC_Element by the relation *characteristic*. It has three subtypes: LC_GrowthFormCharacteristic, LC_ArtificialSurfaceCharacteristic, and LC_WaterAndAssociatedSurfaceCharacteristic. A constraint limits the application of a specific characteristic to either an element or a whole class. That is, the same characteristic cannot be applied at two levels of the metalanguage hierarchy at the same time. This is represented in Figure 26.

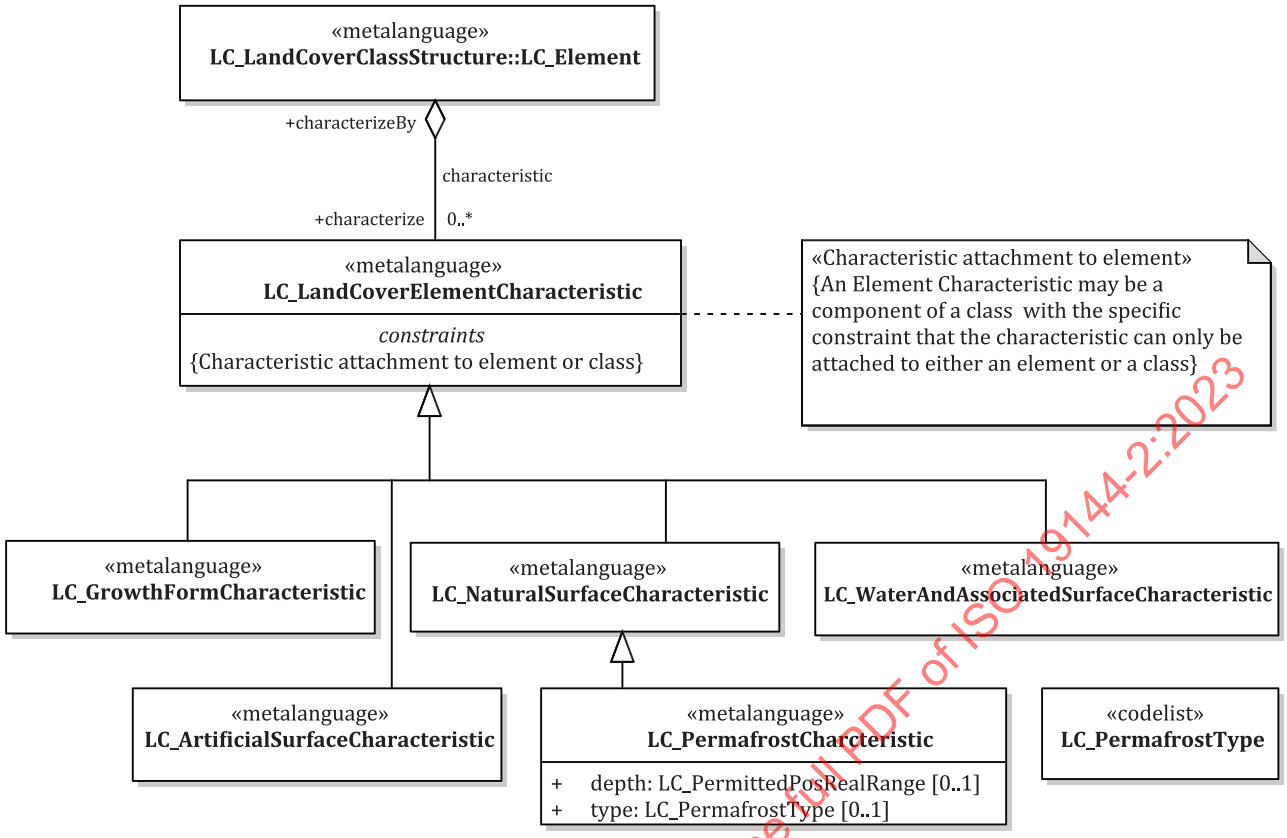


Figure 26 — Subtypes of LC_LandCoverElementCharacteristic

8.22.2 LC_LandCoverElementCharacteristic classes

8.22.2.1 LC_GrowthFormCharacteristic

The LC_GrowthFormCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. The growth form characteristic allows certain morphological features in common for a group of plants to be specified. This component can be used to refine the metalanguage object corresponding to an LC_Element object with respect to growth form to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.22.2.2 LC_ArtificialSurfaceCharacteristic

The LC_ArtificialSurfaceCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_Element object with respect to an artificial surface characteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.22.2.3 LC_WaterAndAssociatedSurfaceCharacteristic

The LC_WaterAndAssociatedSurfaceCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_Element object with respect to a water and associated surface characteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.22.2.4 LC_NaturalSurfaceCharacteristic

The LC_NaturalSurfaceCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_Element object

with respect to a natural surface characteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. This class has one subtype: LC_Permafrost. This characteristic can be extended by registration.

8.22.2.5 LC_PermafrostCharacteristic

The LC_PermafrostCharacteristic metalanguage object is a subtype of LC_NaturalSurfaceCharacteristic. It has two attributes: *permafrostType* and *depth*. The permitted value of the attribute *permafrostType* is described by the enumerated value object LC_PermafrostType. The permitted values of the attribute *depth* are described by the value object LC_PermittedPosRealRange.

NOTE Depth is negative to height. It is a measurable value, so it is represented as a range. A range value such as a depth described over an area is a representative value.

Other attributes can be established through registration.

8.22.2.6 LC_PermafrostType

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

8.23 LC_GrowthFormCharacteristic

8.23.1 LC_GrowthFormCharacteristic subtypes

The LC_GrowthFormCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. The component LC_GrowthFormCharacteristic is related to the LC_VegetationElement metalanguage object by the relation *growthFormCharacteristics*. This same relationship, of course, also applies to the metalanguage object LC_GrowthForm which is a subtype of LC_VegetationElement. 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.

LC_GrowthFormCharacteristic has 11 subtypes:

— LC_FloristicAspectCharacteristic

— LC_AllometricMeasurementCharacteristic

— LC_GrowthFormAgeCharacteristic

— LC_BurntStatusCharacteristic

— LC_DeadStatusCharacteristic

— LC_WaterStressCharacteristic

— LC_VegetationDamageCharacteristic

— LC_GrowthFormIllnessCharacteristic

— LC_GrazedCharacteristic

— LC_MowedCharacteristic

— LC_VegetationArtificialityCharacteristic.

This is represented in Figure 27.

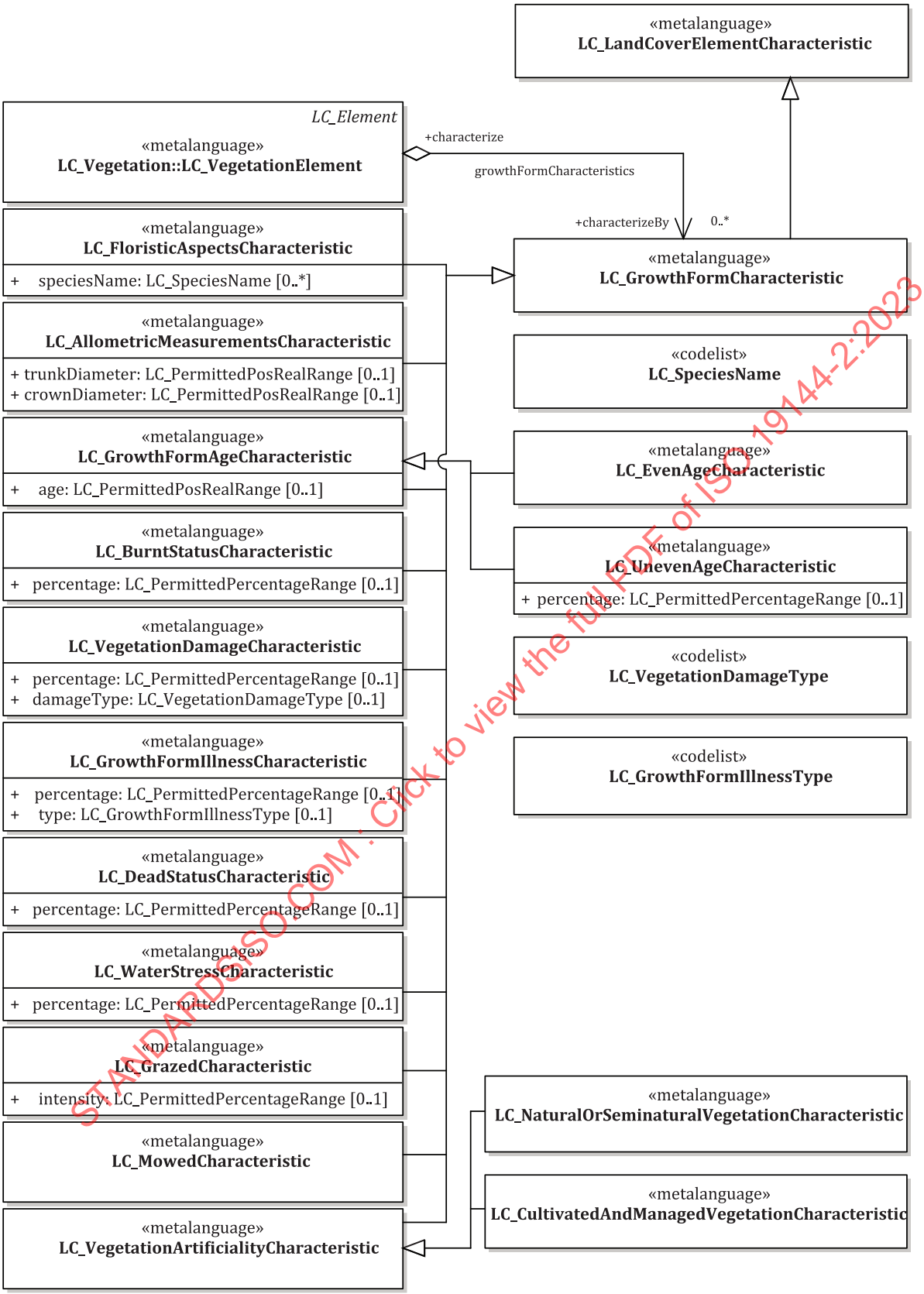


Figure 27 — Subtypes of LC_GrowthFormCharacteristic

8.23.2 LC_GrowthFormCharacteristic classes

8.23.2.1 LC_FloristicAspectsCharacteristic

The LC_FloristicAspectsCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has one optional attribute: *speciesName*. The permitted values of the attribute *speciesName* are described by the code list LC_SpeciesName. The species name is derived from a single plant or the dominant or most frequent species in a group of plants. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to its floristic aspect, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

NOTE At the meta language level the code list SpeciesName is empty. It can be populated by registrationor treated as a character string. Species name can differ in different languages. It is preferable to use the scientific name where possible.

8.23.2.2 LC_AllometricMeasurementsCharacteristic

The LC_AllometricMeasurements component is a subtype of LC_GrowthFormCharacteristic. It has two optional attributes: *trunkDiameter* and *crownDiameter*. The permitted values of the attribute *trunkDiameter* are described by the value object LC_PermittedPosRealRange. The permitted values of the attribute *crownDiameter* are described by the value object LC_PermittedPosRealRange. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to its allometric measurement characteristics of the growth form, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.3 LC_GrowthFormAgeCharacteristic

The LC_GrowthFormAgeCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has one optional attribute: *age*. The permitted values of the attribute *age* are described by the value object LC_PermittedPosRealRange. It also has two subtypes: LC_EvenAge and LC_UnevenAge. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic UML class with respect to the age of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.4 LC_EvenAgeCharacteristic

The LC_EvenAgeCharacteristic component is a subtype of LC_GrowthFormAgeCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormAgeCharacteristic object with respect to the age of a specific vegetative layer, where there is an even age within the growth form strata, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

EXAMPLE An example would be an afforestation where the trees are planted at the same time, but where the forest is not necessarily managed. This is different from a forest that follows a full natural cycle.

8.23.2.5 LC_UnevenAgeCharacteristic

The LC_UnevenAgeCharacteristic component is a subtype of LC_GrowthFormAgeCharacteristic. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. This attribute describes the percentage of each group of plants having the same age. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormAgeCharacteristic class with respect to the age of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

EXAMPLE A forest inventory can use this characteristic, where the percentage of the different age groups of plants can be recorded.

8.23.2.6 LC_BurntStatusCharacteristic

The LC_BurntStatusCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. This attribute describes the percentage of each group of plants which have been affected by fire to an extent that they are no longer able to regenerate. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to burnt status, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.7 LC_VegetationDamageCharacteristic

The LC_VegetationDamageCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has two attributes: *percentage* and optionally *damageType*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. The permitted values of the attribute *damageType* are described by the enumerated value object LC_VegetationDamageType. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to water stress to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.8 LC_GrowthFormIllnessCharacteristic

The LC_GrowthFormIllnessCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has two attributes: *percentage* and optionally *type*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. The permitted values of the attribute *type* are described by the code list LC_GrowthFormIllnessType. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to growth form illness, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.9 LC_DeadStatusCharacteristic

The LC_DeadStatusCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. This attribute describes the percentage of a growth form which has died. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to dead status, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.10 LC_WaterStressCharacteristic

The LC_WaterStressCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has one attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. This attribute describes the percentage of plants that are water stressed. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to water stress, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.11 LC_GrazedCharacteristic

The LC_GrazedCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has one attribute: *intensity*. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to the grazing of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. LC_GrazedCharacteristic addresses only the physiognomic appearance of grazed land. The attribute *intensity* describes the intensity of grazing on percentage basis, from light to heavy grazing, represented as a LC_PermittedPercentageRange. The Land Use activity of grazing is described in ISO/TS 19144-3.

8.23.2.12 LC_MowedCharacteristic

The LC_MowedCharacteristic component is a subtype of LC_GrowthFormCharacteristicCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to the mowing of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. LC_MowedCharacteristic addresses only the physiognomic appearance of mowed land. The Land Use activity of mowing is described in ISO/TS 19144-3.

8.23.2.13 LC_VegetationArtificialityCharacteristic

The LC_VegetationArtificialityCharacteristic component is a subtype of LC_GrowthFormCharacteristic. It has two subtypes: LC_NaturalOrSeminaturalVegetationCharacteristic and LC_CultivatedAndManagedVegetationCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to the artificiality of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.14 LC_NaturalOrSeminaturalVegetationCharacteristic

The LC_NaturalOrSeminaturalVegetationCharacteristic component is a subtype of LC_VegetationArtificialityCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_VegetationArtificiality object with respect to the artificiality of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.15 LC_CultivatedAndManagedVegetationCharacteristic

The LC_CultivatedAndManagedVegetationCharacteristic component is a subtype of LC_VegetationArtificialityCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_VegetationArtificiality object with respect to the artificiality of a specific vegetative layer, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.23.2.16 LC_SpeciesName

The code list LC_SpeciesName contains a list of species names. At the metalanguage level this list is empty, but it can be populated through registration.

8.23.2.17 LC_VegetationDamageType

The code list LC_VegetationDamageType allows a list of damage types to be described. At the metalanguage level this list is empty, but it can be populated through registration.

8.23.2.18 LC_GrowthFormIllnessType

The code list LC_GrowthFormIllnessType allows a list of growth form illness types to be described. At the metalanguage level this list is empty, but it can be populated through registration.

8.24 LC_NameAttributionCriteria

8.24.1 LC_NameAttributionCriteria subtypes

The LC_NameAttributionCriteriaCharacteristic metalanguage object is a component of LC_FloristicAspectCharacteristic through the relationship *nameAttributionCriteria* and has two subtypes: LC_SinglePlantSpeciesCharacteristic and LC_GroupOfPlantSpeciesCharacteristic. These two subtypes

correspond to the two cases where a floristic name is derived from a single plant species or a group of plant species.

This component can be used to refine the metalanguage object corresponding to an LC_FloristicAspectCharacteristic object with respect to species name to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. This is represented in Figure 28.

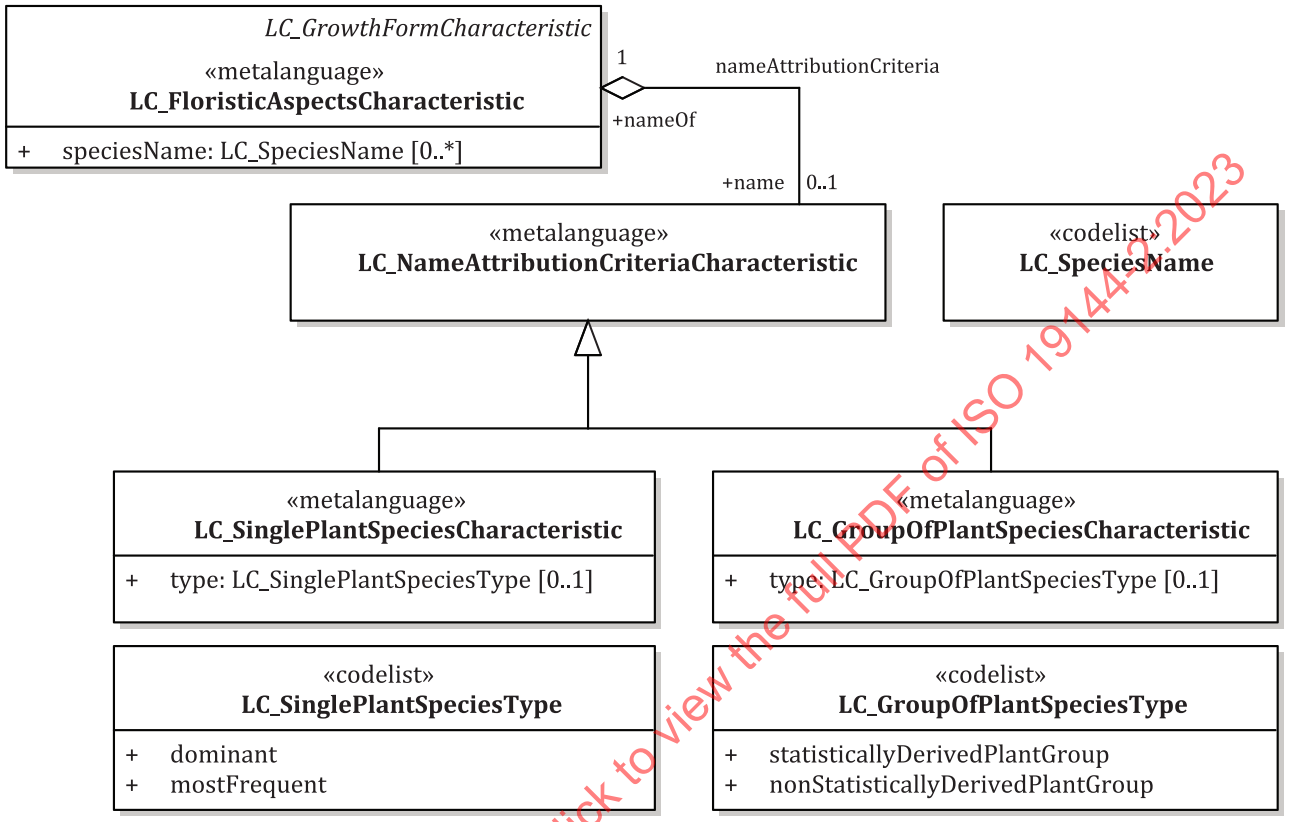


Figure 28 — Subtypes of LC_NameAttributionCriteria

8.24.2 LC_NameAttributionCriteria classes

8.24.2.1 LC_NameAttributionCriteriaCharacteristic

The LC_NameAttributionCriteriaCharacteristic component metalanguage object is a component of LC_FloristicAspectsCharacteristic. It has two subtypes: LC_SinglePlantSpeciesCharacteristic and LC_GroupOfPlantSpeciesCharacteristic.

8.24.2.2 LC_SinglePlantSpeciesCharacteristic

The LC_SinglePlantSpeciesCharacteristic component metalanguage object is a subtype of LC_NameAttributionCriteriaCharacteristic. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_SinglePlantSpeciesType.

8.24.2.3 LC_GroupOfPlantSpeciesCharacteristic

The LC_GroupOfPlantSpeciesCharacteristic component metalanguage object is a subtype of LC_NameAttributionCriteriaCharacteristic. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_GroupOfPlantSpeciesType.

8.24.2.4 LC_SinglePlantSpeciesType

The code list UML class LC_SinglePlantSpeciesType contains a list of characteristics of plant species naming criteria. This list contains two types:

— dominant: dominant plant species type;

— mostFrequent: most frequent plant species type.

This list can be extended through registration.

8.24.2.5 LC_GroupOfPlantSpeciesType

The code list LC_GroupOfPlantSpeciesType contains a list of types of methods used for naming groups of plants. This list contains two types:

— statisticallyDerivedPlantGroup: statistically derived plant species type;

— nonStatisticallyDerivedPlantGroup: non-statistically derived plant species type.

This list can be extended through registration.

8.25 LC_CultivatedAndManagedVegetationCharacteristic

8.25.1 LC_CultivatedAndManagedVegetationCharacteristic subtypes

The LC_CultivatedAndManagedVegetationCharacteristic component is a subtype of LC_VegetationArtificialityCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_VegetationArtificialityCharacteristic object with respect to the artificiality of a specific vegetative layer to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

CultivatedAndManagedVegetation has 7 subtypes:

— LC_CropYieldCharacteristic;

— LC_PlantationCharacteristic;

— LC_CropGrowingParameterCharacteristic;

— LC_WaterSupplyPeriodCharacteristic;

— LC_FieldSizeCharacteristic;

— LC_MechanicalErosionControlCharacteristic;

— LC_PloughedCharacteristic.

This is represented in Figure 29.

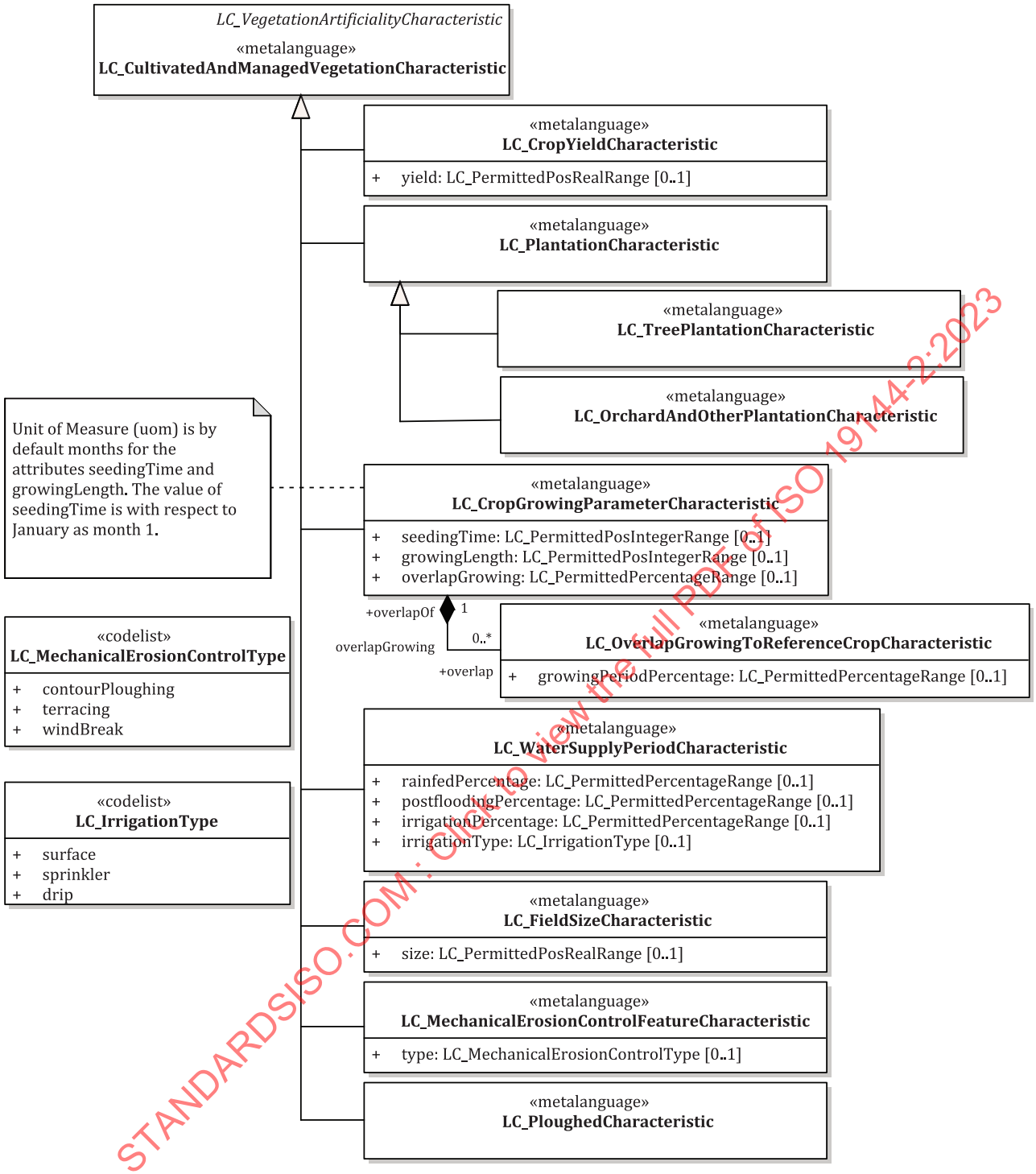


Figure 29 — Subtypes of LC_CultivatedAndManagedVegetationCharacteristic

8.25.2 LC_CultivatedAndManagedVegetationCharacteristic classes

8.25.2.1 LC_CropYield

The LC_CropYieldCharacteristic component metalanguage object is a subtype of LC_CultivatedAndManagedVegetationCharacteristic. It has one attribute: *yield*. The permitted values of the attribute *yield* are described by the value object LC_PermittedPosRealRange. There is no default value for the unit of measure (uom) for the attribute *yield*, so the attribute *uom*, available as part of the LC_PermittedPosRealRange, will need to be used. This component can be used to refine the metalanguage

object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.2 LC_PlantationCharacteristic

The LC_PlantationCharacteristic component metalanguage object is a subtype of LC_CultivatedAndManagedVegetationCharacteristic.Ithastwosubtypes:LC_ForestPlantationCharacteristic and LC_OrchardAndOtherPlantationCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.3 LC_TreePlantationCharacteristic

The LC_TreePlantationCharacteristic component metalanguage object is a subtype of LC_PlantationCharacteristic. The purpose of the plantation is to produce trees such as for timber, fire wood, etc. The plants are cyclically harvested. This class addresses only the biophysical physiognomic aspect of a plantation. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object, by indicating that it is forest plantation, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.4 LC_OrchardAndOtherPlantationCharacteristic

The LC_OrchardAndOtherPlantationCharacteristic component metalanguage object is a subtype of LC_PlantationCharacteristic. The purpose of the plantation is to produce an output from the plants such as a crop. The plants remain. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object, by indicating that it is orchard or other plantation, to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.5 LC_OverlapGrowingToReferenceCropCharacteristic

The component LC_OverlapGrowingToReferenceCropCharacteristic is related to LC_CropGrowingParameterCharacteristic class by the relation *overlapGrowing*. It has one optional attribute: *growingPeriodPercentage*. The permitted values of the attribute *growingPeriodPercentage* are described by the value object LC_PermittedPercentageRange. The component LC_OverlapGrowingToReferenceCropCharacteristic can be used to refine the metalanguage object LC_CropGrowingParameterCharacteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. This component allows for the description of intercropping cultivation. This occurs when the second crop begins to grow during the growth period of the first crop. This is in addition to a description of the *sequentialTemporalRelationship.*

EXAMPLE An example is the growth of beans intercropped after some time with chick peas in Rwanda and Burundi.

8.25.2.6 LC_CropGrowingParameter

The LC_CropGrowingParameter component metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has three optional attributes: *seedingTime*, *growingLength* and *overlapGrowing* and a component LC_OverlapGrowingToReferenceCrop. The permitted values of the attribute *seedingTime* are described by the value object LC_PermittedPosIntegerRange. The permitted values of the attribute *growingLength* are described by the value object LC_PermittedPosIntegerRange. 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 *seedingTime* uses January as month 1.

The permitted values of the attribute *overlapGrowing* are described by the value object LC_PermittedPercentageRange. This component can be used to refine the metalanguage object

corresponding to an LC_CultivatedAndManagedVegetation object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.7 LC_WaterSupplyPeriodCharacteristic

The LC_WaterSupplyPeriodCharacteristic metalanguage object is a subtype of LC_CultivatedAndManagedVegetationCharacteristic. It has four optional attributes: *rainfedPercentage*, *postfloodingPercentage*, *irrigationPercentage* and *irrigationType*. The permitted values of the attributes *rainfedPercentage*, *postfloodingPercentage*, and *irrigationPercentage* are described by the value object LC_PermittedPercentageRange. The permitted values of the attribute *type* are described by the code list LC_IrrigationType. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.8 LC_FieldSizeCharacteristic

The LC_FieldSizeCharacteristic metalanguage object is a subtype of LC_CultivatedAndManagedVegetationCharacteristic. It has one attribute: *size*. LC_FieldSizeCharacteristic is not the geometric shape of the instance. It corresponds to the size of individual fields or plots within a geometric area. The optional *size* attribute relates to size of the individual fields or plots within a geometric area and is an indication of the type of agriculture being performed.

EXAMPLE A large geometric area can be covered by a few major industrial farms, or many small market garden plots.

The permitted values of the attribute *size* are described by the value object LC_PermittedPosRealRange. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.25.2.9 LC_MechanicalErosionControlFeatureCharacteristic

The LC_MechanicalErosionControlFeatureCharacteristic metalanguage object is a subtype of LC_CultivatedAndManagedVegetationCharacteristic. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_MechanicalErosionControlFeatureType. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetationCharacteristic object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. The result of a human activity can result in a physiognomic modification of a land aspect. This is the case for a human activity for erosion control that can result in specific Land Cover features.

EXAMPLE Examples of the LC_MechanicalErosionControlFeatureCharacteristic are terracing or contour ploughing.

8.25.2.10 LC_Ploughed

The LC_PloughedCharacteristic metalanguage object is a subtype of LC_CultivatedAndManagedVegetationCharacteristic. This component can be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetation object to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. LC_PloughedCharacteristic addresses only the physignominic appearance of plougher land. The Land Use activity of plowing is described in ISO/TS 19144-3.

8.25.2.11 LC_IrrigationType

The code list LC_IrrigationType contains a list of irrigation types. This list contains three types:

— surface: surface irrigation type;

— sprinkler: sprinkler irrigation type;

— drip: drip irrigation type.

This list can be extended through registration.

8.25.2.12 LC_MechanicalErosionControlFeatureType

The code list LC_MechanicalErosionControlFeatureType contains a list of mechanical erosion control types. This list contains three types:

— contourPloughing: contour ploughing erosion control;

— terracing: terracing erosion control;

— windBreak: wind break erosion control.

This list can be extended through registration.

8.26 LC_ArtificialSurfaceCharacteristic

8.26.1 LC_ArtificialSurfaceCharacteristic subtypes

The LC_ArtificialSurfaceCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. The component LC_ArtificialSurfaceCharacteristic is related to the LC_ArtificialSurfaceElement metalanguage object by the relation *artificialSurfaceCharacteristic*. It has three subtypes: LC_ConstructionStatusCharacteristic, LC_ArtificialSurfaceCategoryCharacteristic and LC_ArtificialSurfaceDamageCharacteristic. There can be 0 to many LC_ArtificialSurfaceCharacteristic(s) associated with LC_ArtificialSurfaceElement. 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. This is represented in Figure 30.

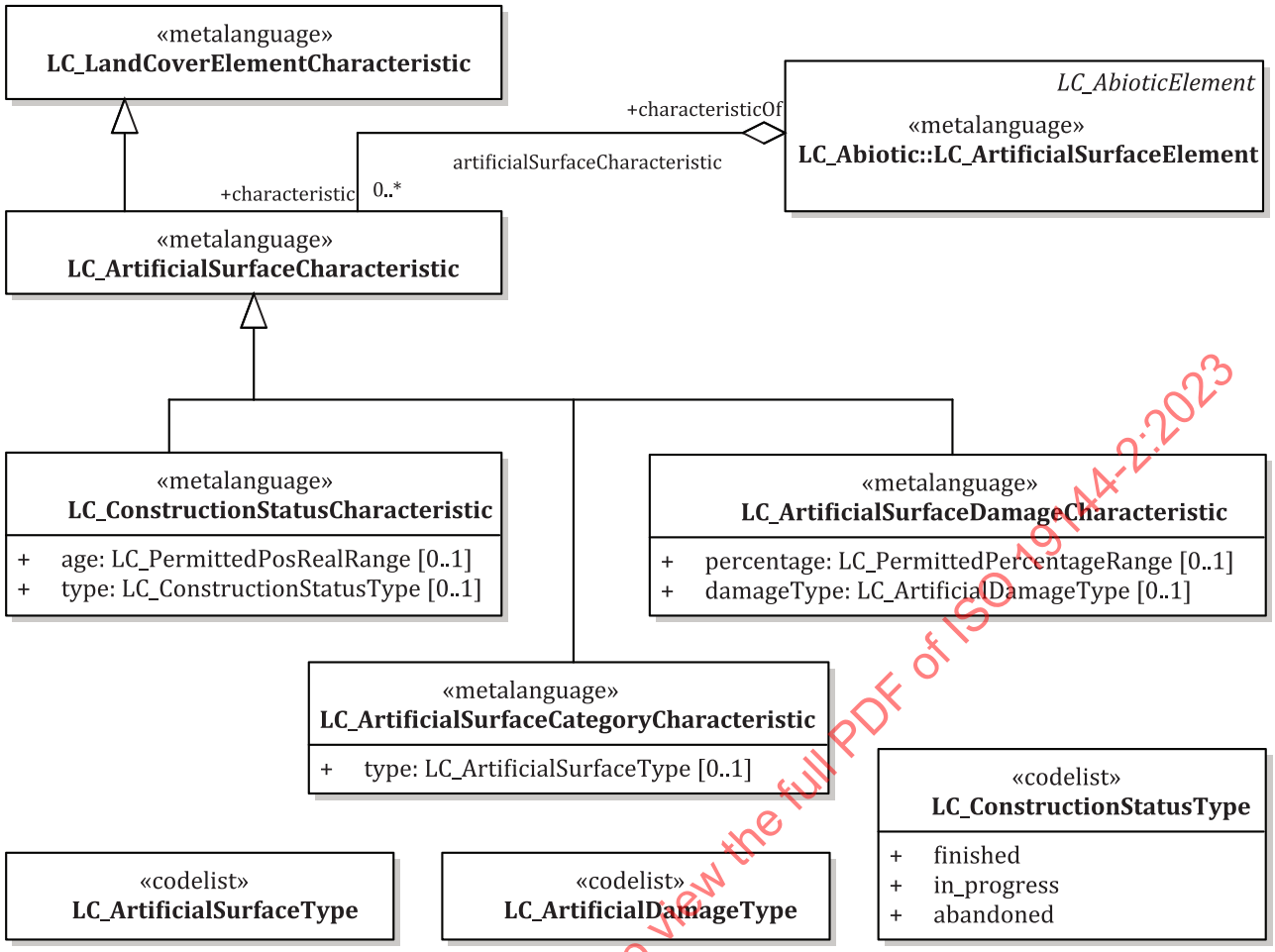


Figure 30 — Subtypes of LC_ArtificialSurfaceCharacteristic

8.26.2 LC_ArtificialSurfaceCharacteristic classes

8.26.2.1 LC_ConstructionStatusCharacteristic

The LC_ConstructionStatusCharacteristic component metalanguage object is a subtype of LC_ArtificialSurfaceCharacteristic. It has two optional attributes: *age* and *type*. The permitted values of the attribute *age* are described by the value object LC_PermittedPosRealRange. The permitted values of the attribute *type* are described by the code list LC_ConstructionStatusType. This component can be used to refine the metalanguage object corresponding to an LC_ArtificialSurfaceCharacteristic UML class to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.26.2.2 LC_ArtificialSurfaceCategoryCharacteristic

The LC_ArtificialSurfaceCategoryCharacteristic component metalanguage object is a subtype of LC_ArtificialSurfaceCharacteristic. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_ArtificialSurfaceType. This component can be used to refine the metalanguage object corresponding to an LC_ArtificialSurfaceCharacteristic UML class to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.26.2.3 LC_ArtificialSurfaceDamageCharacteristic

The LC_ArtificialSurfaceDamageCharacteristic component is a subtype of LC_ArtificialSurfaceCharacteristic. It has two attributes: *percentage* and optionally *damageType*.

The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageRange. The permitted values of the attribute *damageType* are described by the enumerated value object LC_ArtificialDamageType. This component can be used to refine the metalanguage object corresponding to an LC_ArtificialSurfaceCharacteristic object with respect to water stress to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.26.2.4 LC_ArtificialDamageType

The code list LC_ArtificialDamageType allows a list of damage types to be described. At the metalanguage level this list is empty, but it can be populated through registration.

8.26.2.5 LC_ArtificialSurfaceType

The code list LC_ArtificialSurfaceType allows a list of surface types to be described. The artificial surface type describes the generic name of an artificial surface. This name is defined in accordance to its external aspect/appearance and its generic intended use. At the metalanguage level this list is empty, but it can be populated through registration.

8.26.2.6 LC_ConstructionStatusType

The code list LC_ConstructionStatusType contains a list of types describing the status of construction. This list contains three types:

— finished;

— in-progress;

— abandoned.

This list can be extended through registration.

8.27 LC_WaterAndAssociatedSurfaceCharacteristic

8.27.1 LC_WaterAndAssociatedSurfaceCharacteristic subtypes

The LC_WaterAndAssociatedSurfaceCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. The LC_WaterAndAssociatedSurfacesCharacteristic metalanguage object is a component related to the LC_WaterBodyAndAssociatedSurfaceElement metalanguage object by the relation waterBodyAndAssociatedSurfaceCharacteristic. It has five subtypes: LC_ArtificialityCharacteristic, LC_WaterSalinityCharacteristic, LC_SnowCategoryCharacteristic, LC_IceCategoryCharacteristic and LC_WaterChemistryCharacteristic. The component LC_WaterAndAssociatedSurfaceCharacteristic can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElement to permit the generation of a more specific Land Cover feature class in a Land Cover classification system. This is represented in Figure 31.

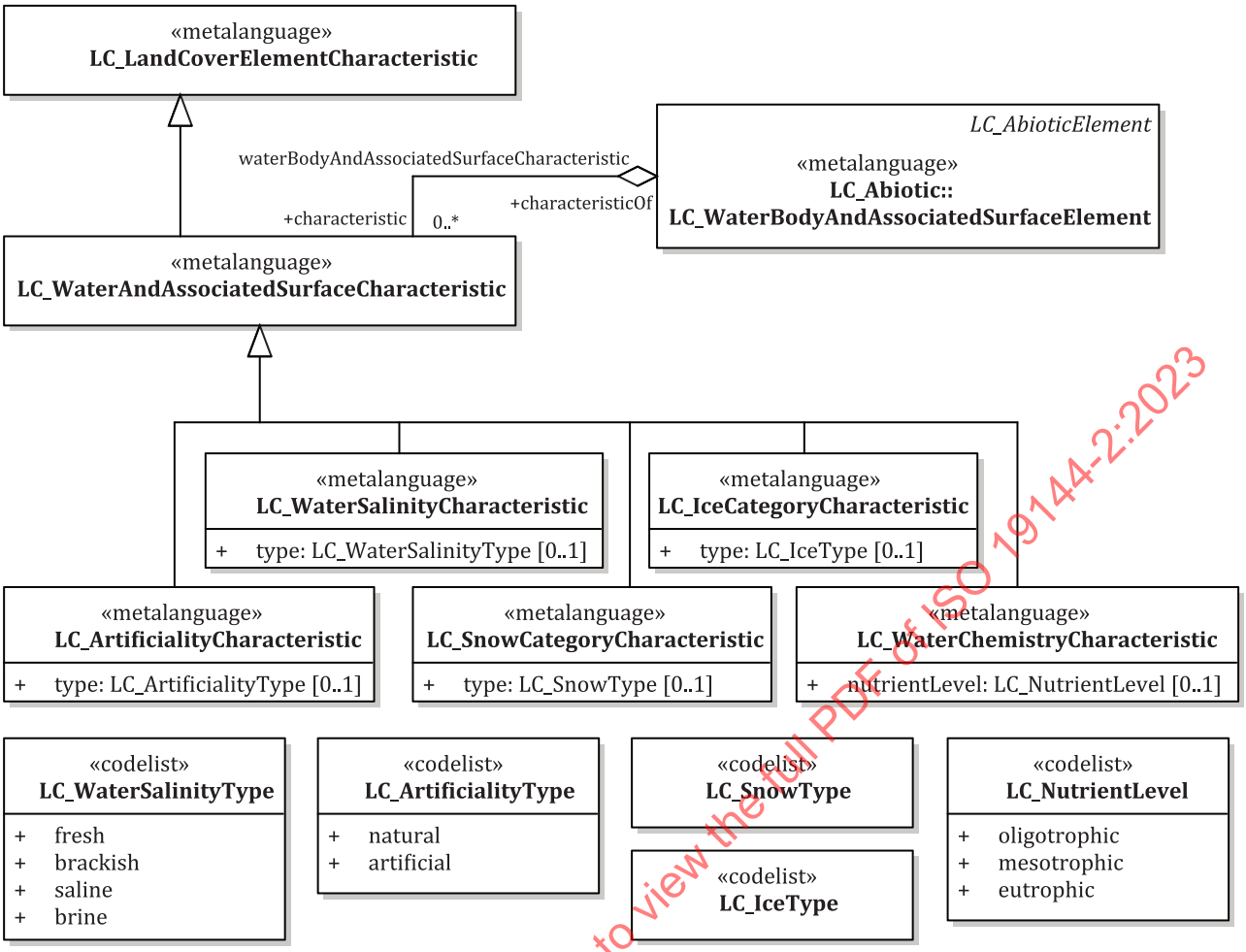


Figure 31 — Subtypes of LC_WaterAndAssociatedSurfaceCharacteristic

8.27.2 LC_WaterAndAssociatedSurfaceCharacteristic classes

8.27.2.1 LC_ArtificialityCharacteristic

The LC_ArtificialityCharacteristic component metalanguage object is a subtype of LC_WaterAndAssociatedSurfacesCharacteristic component. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_ArtificialityType. The component LC_Artificiality can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElementCharacteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.27.2.2 LC_WaterSalinityCharacteristic

The LC_WaterSalinityCharacteristic component metalanguage object is a subtype of LC_WaterAndAssociatedSurfacesCharacteristic component. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_WaterSalinityType. The component LC_WaterSalinity can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElementCharacteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.27.2.3 LC_SnowCategoryCharacteristic

The LC_SnowCategoryCharacteristic component metalanguage object is a subtype of LC_WaterAndAssociatedSurfacesCharacteristic component. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_SnowType. The component LC_SnowCategory can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElementCharacteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.27.2.4 LC_IceCategoryCharacteristic

The LC_IceCategoryCharacteristic component metalanguage object is a subtype of LC_WaterAndAssociatedSurfacesCharacteristic component. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_IceType. The component LC_IceCategory can be used to refine the metalanguage object LC_WaterBodyAndAssociatedSurfaceElementCharacteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.27.2.5 LC_WaterChemistryCharacteristic

The LC_WaterChemistryCharacteristic component is a subtype of LC_WaterAndAssociatedSurfacesCharacteristic. It has one attribute: *nutrientLevel*. The permitted values of the attribute *nutrientLevel* are described by the value object LC_NutrientLevel. This component can be used to refine the LC_WaterBodyAndAssociatedSurfaceElementCharacteristic to permit the generation of a more specific Land Cover feature class in a Land Cover classification system.

8.27.2.6 LC_ArtificialityType

The code list LC_ArtificialityType contains a list of artificiality types. This list contains two types: natural and artificial. The list can be extended through registration.

8.27.2.7 LC_WaterSalinityType

The code list LC_WaterSalinityType contains a list of water salinity types. This list contains four types: fresh, brackish, saline and brine. The list can be extended through registration.

8.27.2.8 LC_SnowType

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

8.27.2.9 LC_IceType

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

8.27.2.10 LC_NutrientLevel

The code list LC_NutrientLevel contains a list of nutrient levels. This list contains three types: oligotrophic, mesotrophic and eutrophic. This list can be extended through registration.

8.28 LC_ValueObject permitted numeric values

8.28.1 LC_ValueObject general description

The LC_ValueObject is a metalanguage object that describes how permitted numerical values at the metalanguage level can be instantiated to the basic number types at the type level. These are

descriptors of permitted types, not actual attributes. Actual number types can be assigned at the Legend or Application Schema level of instantiation.

The basic number types are defined in ISO 19103 and are required for implementation of this document. The LC_ValueClass metalanguage object is an abstract supertype of the three abstract metalanguage value objects LC_PermittedRealValueType, LC_PermittedPercentageValueType and LC_PermittedIntegerValueType. Each of these value objects have subtypes that describe a number and a range. Each of the value objects is described by a constraint that characterizes the type of numerical entity that can be represented by the value object. This is represented in Figure 32.

The LC_PermittedRealValue, LC_PermittedPosRealValue, LC_PermittedPercentageValue and LC_PermittedPosIntegerValue objects can be extended into a range, where the inherited attribute *baseValue* becomes the minimum value of the range and a new attribute *maxValue* describes the maximum value of the range.

These value objects are generators for the actual value objects that will appear in instances of a classification system generated using the LCML. The result of instantiating these objects are value classes taken from the basic types provided in ISO 19103. The results of instantiating a classification system are objects that carry actual values. In the various examples given in this document, value objects have been instantiated from the metalanguage level to the type level and then to the instance level, to produce real objects as needed in an example.

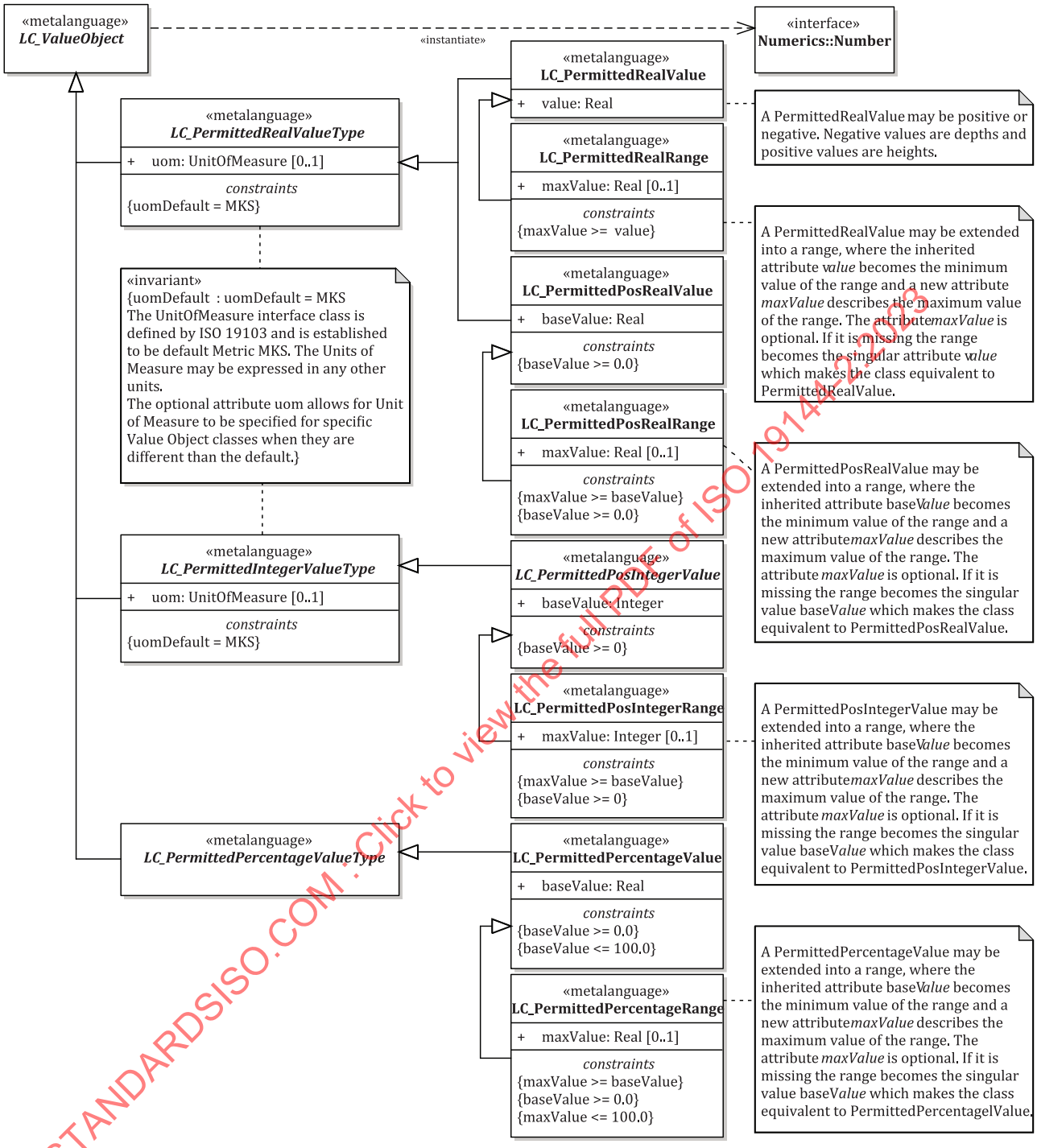


Figure 32 — LC_ValueObject

8.28.2 LC_ValueObject types

8.28.2.1 LC_ValueObject

LCML defines a set of value objects at the metalanguage level that can be instantiated to generate basic types in an Application Schema for a particular type of Land Cover data. That is, the value type metalanguage objects provide constraints on the value ranges when instantiated into ISO 19103-defined basicTypes. It has three subtypes: LC_PermittedRealValueType, LC_PermittedPercentageValueType, and LC_PermittedIntegerValueType.

The UnitOfMeasure interface class is defined by ISO 19103 and is established to be default Metric MKS (Metres, Kilograms, Seconds), as per "The International System of Units".[48] The units of measure may be expressed in any other units by the use of the *uom* attribute on LC_PermittedRealValueType and LC_PermittedIntegerValueType. The optional attribute *uom* allows for unit of measure to be specified for specific Value Object classes when they are different than the default.

8.28.2.2 Number

Number is a UML class from the ISO 19103 basicTypes package to which the subtypes of LC_ValueObject can be instantiated when describing a particular Land Cover classification system with the LCML metalanguage model.

8.28.2.3 LC_PermittedRealValueType

The LC_PermittedRealValueType metalanguage object is a subtype of LC_ValueObject. It is an abstract metalanguage object for the various types of real number values permitted in the metalanguage whose subtypes can be instantiated as a real number type using the Real type from the basic Primitive Types package in ISO 19103, with constraints. It has three subtypes: LC_PermittedRealValue, LC_PermittedPosRealValue and indirectly LC_PermittedPosRealRange.

LC_PermittedRealValueType has the attribute *uom* which optionally specifies the Unit of Measure. The interface class UnitOfMeasure is defined in accordance with ISO 19103 and is by default Metric MKS.[48] The Units of Measure can be expressed in any other units. The optional attribute *uom* allows for Unit of Measure to be specified for specific Value Object classes when they are different than the default. The constraint *uomDefault* indicates that the optional attribute *uom* is only used when the unit of measure is different than the default. The attribute *uom* has type UnitOfMeasure which is an interface to *uomIdentifier* defined in ISO 19103 which is a CharacterString.

8.28.2.4 LC_PermittedRealValue

The LC_PermittedRealValue metalanguage object is a subtype of LC_PermittedRealValueType. It is a metalanguage object for a real number value permitted in the metalanguage where the attribute *value* can be instantiated as a real number type using the Real type from the basic Primitive Types package in ISO 19103, where the value can be positive or negative. The sign convention is that negative values are depths and positive values are heights.

8.28.2.5 LC_PermittedRealRange

The LC_PermittedRealRange metalanguage object is a subtype of LC_PermittedRealValue and indirectly of LC_PermittedRealValueType. It is a metalanguage object for a real number value range permitted in the metalanguage. The inherited attribute *value* becomes the minimum value of the range and a new attribute *maxValue* describes the maximum value of the range, where the attributes *value* and *maxValue* can be instantiated as a pair of real number types using the Real type from the basic Primitive Types package in ISO 19103, with the constraint: { *value* ≥ *baseValue* }. The attribute *maxValue* is optional. If it is missing, the range becomes the singular attribute *value*, which makes the class equivalent to PermittedRealValue.

8.28.2.6 LC_PermittedPosRealValue

The LC_PermittedPosRealValue metalanguage object is a subtype of LC_PermittedRealValueType. It is a metalanguage object for a positive real number value permitted in the metalanguage where the attribute *baseValue* can be instantiated as a real number type using the Real type from the basic Primitive Types package in ISO 19103, with the constraint { *baseValue* ≥ 0.0 }.

8.28.2.7 LC_PermittedPosRealRange

The LC_PermittedPosRealRange metalanguage object is a subtype of LC_PermittedPosRealValue and indirectly of LC_PermittedRealValueType. It is a metalanguage object for a positive real number value

range permitted in the metalanguage. The inherited attribute *baseValue* becomes the minimum value of the range and a new attribute *maxValue* describes the maximum value of the range, where the attributes *baseValue* and *maxValue* can be instantiated as a pair of real number types using the Real type from the basic Primitive Types package in ISO 19103, with the constraints:

{ *maxValue* ≥ *baseValue*

and *baseValue* ≥ 0.0

and *maxValue* ≥ 0.0 }

The attribute *maxValue* is optional. If it is missing, the range becomes the singular value *baseValue*, which makes the class equivalent to PermittedPosRealValue.

8.28.2.8 LC_PermittedIntegerValueType

The LC_PermittedIntegerValueType metalanguage object is a subtype of LC_ValueObject. It is an abstract metaclass for the various integer number values permitted in the metalanguage whose subtypes can be instantiated as an integer number type using the Integer type from the basic Primitive Types package in ISO 19103, with constraints. It has two subtypes: LC_PermittedPosIntegerValueType, and indirectly LC_PermittedPosIntegerRange.

LC_PermittedIntegerValueType has the attribute *uom* which optionally specifies the unit of measure. The interface class UnitOfMeasure is defined by ISO 19103 and is by default Metric MKS.[48] The units of measure can be expressed in any other units. The optional attribute *uom* allows for unit of measure to be specified for specific Value Object classes when they are different than the default. The constraint uomDefault indicates that the optional attribute *uom* is only used when the unit of measure is different than the default. The attribute *uom* has type UnitOfMeasure which is an interface to uomIdentifier, defined in ISO 19103 which is a CharacterString.

8.28.2.9 LC_PermittedPosIntegerValue

The LC_PermittedPosIntegerValue metalanguage object is a subtype of LC_PermittedPosIntegerValueType. It is a metalanguage object for a positive integer number value permitted in the metalanguage where the attribute *baseValue* can be instantiated as an integer number type using the Integer type from the basic Primitive Types package in ISO 19103, with the constraint:

{ *baseValue* ≥ 0 }.

8.28.2.10 LC_PermittedPosIntegerRange

The LC_PermittedPosIntegerRange metalanguage object is a subtype of LC_PermittedPosIntegerValue and indirectly of LC_PermittedPosIntegerValueType. It is a metalanguage object for a positive integer number value range permitted in the metalanguage. The inherited attribute *baseValue* becomes the minimum value of the range and a new attribute *maxValue* describes the maximum value of the range, where the attributes *baseValue* and *maxValue* can be instantiated as a pair of integer number types using the Integer type from the basic Primitive Types package in ISO 19103, with the constraints:

{ *maxValue* ≥ *baseValue*

and *baseValue* ≥ 0}.

The attribute *maxValue* is optional. If it is missing, the range becomes the singular value *baseValue*, which makes the class equivalent to PermittedPosIntegerValue.

8.28.2.11 LC_PermittedPercentageValueType

The LC_PermittedPercentageValueType metalanguage object is a subtype of LC_ValueObject. It is a metalanguage object for the various types of percentage values permitted in the metalanguage whose subtypes can be instantiated as a real number types using the Real type from the basic Primitive Types

package in ISO 19103, with constraints. It has two subtypes: LC_PermittedPercentageValueType and indirectly LC_PermittedPercentageRange.

8.28.2.12 LC_PermittedPercentageValue

The LC_PermittedPercentageValue metalanguage object is a subtype of LC_PermittedPercentageValueType. It is a metalanguage object for a positive integer number value permitted in the metalanguage where the attribute *baseValue* can be instantiated as an integer number type using the Integer type from the basic Primitive Types package in ISO 19103, with the constraint:

{ *baseValue* ≥ 0.0

and *maxValue* ≤ 100.0 }.

8.28.2.13 LC_PermittedPercentageRange

The LC_PermittedPercentageRange metalanguage object is a subtype of LC_PermittedPercentageValue and indirectly of LC_PermittedPercentageValueType. It is a metalanguage object for a positive percentage number value range permitted in the metalanguage. The inherited attribute *baseValue* becomes the minimum value of the range and a new attribute *maxValue* describes the maximum value of the range, where the attributes *baseValue* and *maxValue* can be instantiated as a pair of real number types using the Real type from the basic Primitive Types package in ISO 19103, with the constraints:

{ *maxValue* ≥ *baseValue*

and *baseValue* ≥ 0.0

and *maxValue* ≤ 100.0 }.

The attribute *maxValue* is optional. If it is missing, the range becomes the singular value *baseValue*, which makes the class equivalent to PermittedPercentageValue.

9 Extension of the LCML

9.1 Extension process

The LCML contains a set of fixed metalanguage elements that are the basic vocabulary for describing different Land Cover classification systems. This vocabulary has to be stable in order for descriptions of different Land Cover classification systems to be comparable. Therefore, the subtypes of the UML class LC_Element in the model used to express the metalanguage are only allowed to be changed by amendment of this document. This allows for a route to extend the language that is well controlled by the standardization process.

9.2 Registration of extensions

Changes to the properties Land Cover element characteristics and Land Cover class characteristics as expressed in the metalanguage objects LC_LandCoverElementCharacteristic and LC_LandCoverClassStructure can be made by registration in conformance with the registration rules described in the future ISO 19144-4.[5)] This provides a simple route to extend the descriptive aspects of the metalanguage without changing the basic metalanguage elements. It also permits the characteristics and associated code lists to be extended.

Additions can also be made to the subtypes of the UML class LC_Element or the components, attributes or code lists associated with these metalanguage objects by registration. This is an addition to the subtypes of LC_Element, not a change.

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

The future ISO 19144-4 will define the structure of the register, not its contents. The contents can be established by a national body or other user who would establish their own instance of the register. A user of the register could make a perfect description of their national Land Cover classification system using the elements defined in this document plus additional registered extensions. A comparison of two Land Cover classification systems using the LCML would be based on the common elements defined in this document and on a comparison of the additional extensions nationally registered.

The responsibility for a register to extend the LCML by registration rests with the national body or organization which wishes to extend the LCML. The national body or organization would setup their own register. Other national bodies or organizations could also set up other equivalent registers for their own use. A comparison of two Land Cover classification systems using the common portion of the LCML, as defined in this document, will only be to the level of detail addressed by the metalanguage objects and attributes that have been standardized. To do a comparison to a more detailed level will require an examination of the Land Cover classification system in terms of the registered items in one or both registers.

NOTE The register for extension of the metalanguage is different in purpose from the register identified in ISO 19144-1. The register identified in ISO 19144-1 is used to record the Legend Classes produced from a Land Cover or other classification system. The register for extension of the metalanguage is at a different level. It is used to manage any extensions to the metalanguage objects in the LCML or changes to the characteristics.

Requirement 3: Extensions to the metalanguage by the subtyping of UML class LC_Element or the components, attributes or code lists associated with these metalanguage objects, or extension to the properties of Land Cover element characteristics and/or Land Cover class characteristics shall be carried out through a registration process.

9.3 Backward compatibility through registration

Since one of the primary purposes of the LCML is to allow for comparison between different Land Cover classification systems, it is important that any changes to the vocabulary of the metalanguage be well controlled and be backward compatible. None of the metalanguage objects can be deleted from the model. They can be extended with additional UML attributes. If a subobject needs to be altered, an additional subobject can be defined to replace that object, leaving the old object in place for backward compatibility as a deprecated object. This is in accordance with the procedures for registration as described in ISO 19135-1.

EXAMPLE If a code list is extended, the old version of the code list is superseded with a new object containing the new list. The old list remains in the register with an old identifier and date. In order for the comparative aspect of the language to work, the relationship between the new registered item class and the deprecated registered item class needs to be described.

The maintenance of backward compatibility in the LCML is required both in the basic metalanguage elements that are the subtypes of LC_Elements, which can only be changed by amendment to this document, and for changes to the metalanguage objects LC_ElementCharacteristic and LC_ClassCharacteristic which can be done by registration.

Requirement 4: Any extension or change to the metalanguage shall be backward compatible with ISO 19144-2:2012.

Annex A
(normative)

Abstract test suite

A.1 Overview of abstract test suite

This annex presents the abstract test suite for evaluating conformance to this document. The abstract test suite contains a test module for a classification Ssstem (A.2), and a test module for the comparison of two Land Cover classification systems (A.3).

The name and contact information of the maintenance agency for this document can be found at www.iso.org/maintenance_agencies.

A.2 Conformance of a Land Cover classification system

a) Test purpose: Verify that a Land Cover classification system can be described in terms of the LCML in accordance with Requirement 1.

b) Test method: Inspect the generated model of the Land Cover classification system by composing Land Cover metaclasses (LC_LandCoverClassDescriptor) for each UML class from the Land Cover classification system and then instantiating each UML class to form the Land Cover classification system model. Each UML class in the Land Cover classification system is to be expressed in terms of LC_Elements, LC_LandCoverElementCharacteristic(s) and LC_ClassCharacteristic(s) organized into LC_LandCoverClassDescriptor classes.

c) Reference: Clause 8, including the Land Cover high level UML class structure as defined in 8.5, and the definition of the LC_Elements as defined in 8.7 including all of the subtypes of LC_Element defined in 8.8 to 8.20, and the applicable characteristics as defined in 8.21 to 8.28.

d) URI: https://standards.isotc211.org/19144/-2/1/LandCoverSystem.

e) Test type: Capability.

A.3 Conformance of a comparison process of two Land Cover classification systems

a) Test purpose: Comparison of two Land Cover classification systems to identify the differences in accordance with Requirement 2. This will enable the development of a mapping between the two systems.

b) Test method: Generate a model for each of the Land Cover classification systems by composing Land Cover metalanguage objects (LC_LandCoverClassDescriptor) for each UML class from each of the two Land Cover classification systems and then instantiating each UML class to form two separate Land Cover classification systems models. Each UML class in each of the two the Land Cover classification systems is to be expressed in terms of LC_Elements, LC_LandCoverElementCharacteristic(s) and LC_ClassCharacteristic(s) organized into LC_LandCoverClassDescriptor metalanguage objects in accordance with the LCML. Examine each of the classes between each of the two Land Cover classification systems identifying which are identical because they have the same description using the LCML metalanguage objects, which are generalizations or specializations of each other because they share the same root description using the LCML metalanguage objects, but one or the other classes uses additional metalanguage object descriptor elements or characteristics, and which ones are similar because they share the many of the same LCML metalanguage object descriptor elements

or characteristics but differ on specific metalanguage object descriptor elements or characteristics. From the comparison, generate a mapping between the two Land Cover classification systems.

c) Reference: Clause 8, including the Land Cover high level UML class structure as defined in 8.5, and the definition of the LC_Elements as defined in 8.7, including all of the subtypes of LC_Element defined in 8.8 to 8.20, and the applicable characteristics as defined in in 8.21 to 8.28.

d) URI: https://standards.isotc211.org/19144/-2/1/LC_Comparison.

e) Test type: Capability.

A.4 Extension of the Land Cover Meta Language

a) Test purpose: Verify that extensions to the metalanguage are done through a registration process in accordance with Requirement 3.

b) Test method: Inspect the classes, attributes and code lists used in the generated model of the Land Cover classification system to ensure that any extensions are documented in a manner so that they can be registered.

c) Reference: Subclause 9.2. The details of registration are described in ISO 19144-4.

d) URI: https://standards.isotc211.org/19144/-2/1/MetaLanguageExtension.

e) Test type: Capability.

A.5 Backward compatibility of the Land Cover Meta Language

a) Test purpose: Verify that any extension or change to the metalanguage is backward compatible with the previously published edition of the document in accordance with Requirement 4.

b) Test method: Inspect any extensions to the metalanguage to ensure that extensions to classes are done by subtyping or the development of new independent classes, and that extensions to other components, such as attributes or code lists associated with these metalanguage objects, or extension to the properties of Land Cover element characteristics are done without changing the meaning of existing elements.

c) Reference: Subclause 9.3.

d) URI: https://standards.isotc211.org/19144/-2/1/MetaLanguageBackwardCompatibility.

e) Test type: Capability.

Annex B
(informative)

The relationship of the LCML to the General Feature Model of ISO 19109

There currently exist many different ways to describe Land Cover. Every description is a viewpoint from a particular observer dependant on the objective, methodology and "language" used by the observer. The intent of this document is to establish an approach to compare descriptions and convert data from one descriptive viewpoint to another.

Every classification starts from a universe of discourse, which is the "world of interest". To establish a classification system, the universe of discourse is analysed according to a set of rules. The result is either a classification system or a feature data model to be used within an Application Schema.

A classification system is an exhaustive list of the Land Cover classes that describe the universe of discourse.

EXAMPLE 1 The European CORINE Land Cover System is an example of such a classification system.

The classification system can be used to create an Application Schema. The Application Schema consists of a feature data model including the binding to its geometry and other properties. The feature data model can derive directly from the classification system, or it can be a more structured model such as a parameterized model. It is also possible to directly derive the feature data model from the analysis by rule and then generate the classification rule from the feature data model.

A real data set is an instance of the Application Schema.

This classification system and related Application Schema is unique to a particular point of view, and there are many points of view that are all valid. There is a need for comparing different classification systems and their associate Application Schemas. There is also a need for integrating instances of data sets produced by different systems.

The approach identified in this document is to describe different Land Cover systems using a common Land Cover metalanguage. The metalanguage works at the classification system level. This is illustrated in Figure B.1.

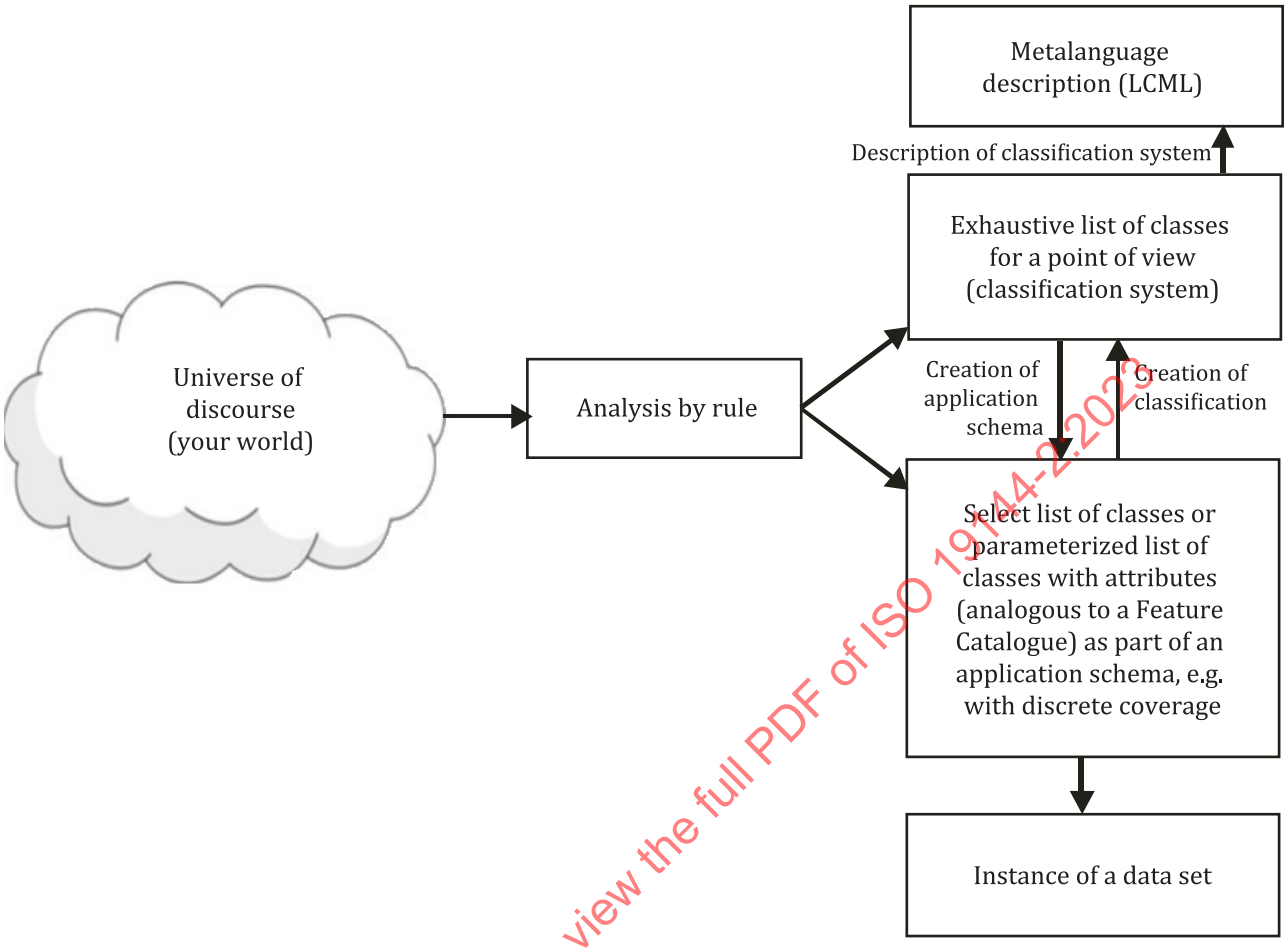


Figure B.1 — Logical framework

The core of the LCML is the composition of an LC_LandCoverClassDescriptor metalanguage object from a set of LC_Element (s). The LCML provides a reference vocabulary of meta elements that is used to create a formal language for describing the Land Cover classes. Harmonization of different classification systems is achieved on the basis of the LCML meta elements forming the classes and not on the basis of the classes themselves.

Figure B.2 shows the levels of abstraction. The LCML metalanguage is at the highest level of abstraction. The instantiation of the metaclasses in the LCML is used to describe different classification systems.

The second level consists of all the different Land Cover classification systems expressing different points of views from different disciplines or from different organizations within a discipline. A classification system describes a dictionary of classifiers. ISO 19144-1 describes how these classifiers can be organized and how they relate to a discrete coverage.

EXAMPLE 2 Examples of Legends derived from the UN FAO LCCS, the USGS Anderson system, or the European CORINE system.

At the third level, Application Schema are used to describe a particular type or a series of data sets. Such Application Schema are conformant with the rules for Application Schema as described in ISO 19109. At the Application Schema level, the classes of the classification system correspond to features in the general feature model of ISO 19109, and the Legend of classes corresponds to a feature catalogue. The set of feature classes can be established as a feature catalogue in conformance with ISO 19110. This is entirely consistent with the use of features in all other types of Application Schemas for geographic information including the use of features to describe the components of a discrete coverage as described in the ISO 19123 series.

At the fourth level, a specific set of data is an instance of the Application Schema.

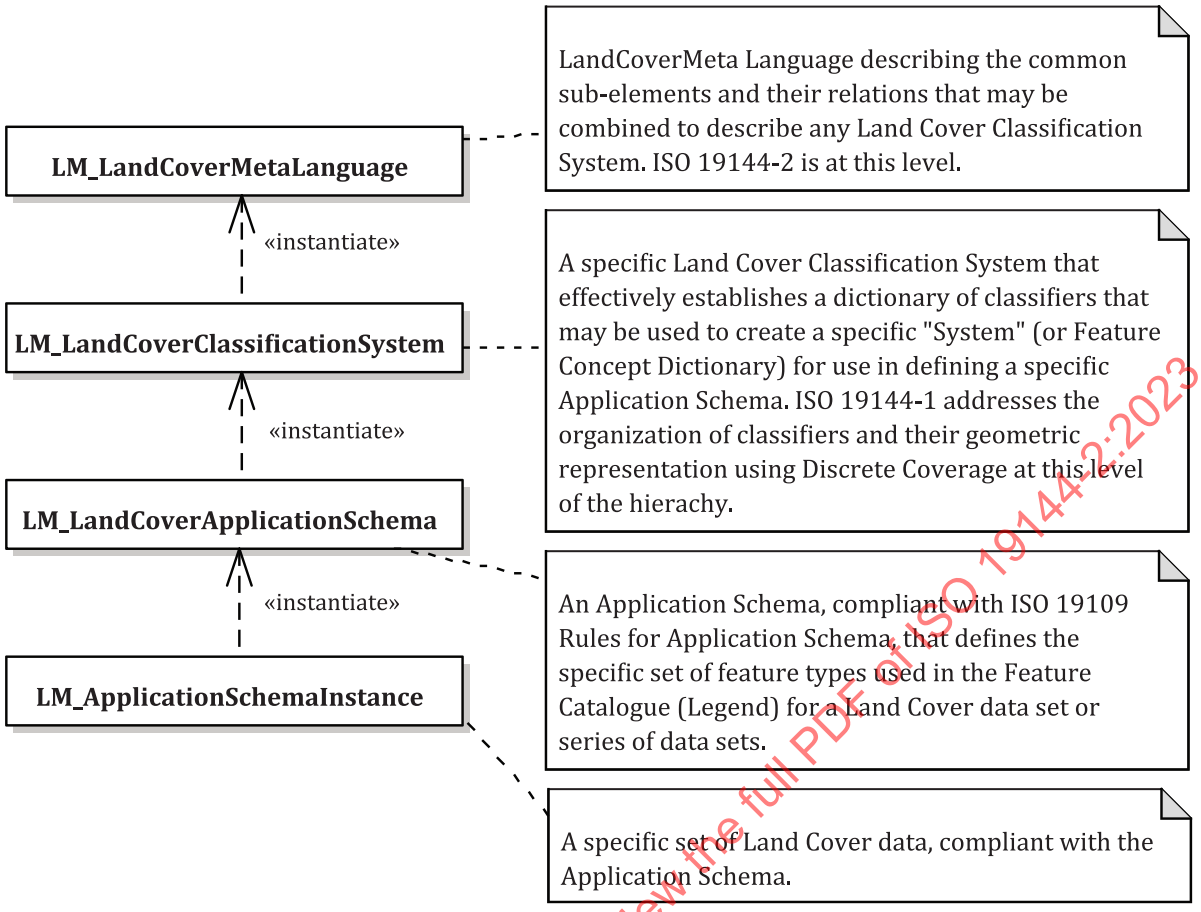


Figure B.2 — Levels of abstraction in the relationship of the LCML to an Application Schema

The reason for these multiple levels of extraction is to solve the underlying interoperability problems related to the use of different definitions for features in different Application Schemas and classification systems. It is not sufficient to simply define a single Application Schema or classification system to address all Land Cover applications because it is impossible for all nations or user communities to agree upon one common point of view. A realistic way to achieve interoperability is to look at the elements that make up the definition at the meta level. Decomposition of a semantic concept into its constituent elements is a common analytical technique to establish an ontology. Classes with shared elements can be compared even though the name of the classification class in different classification systems can be different.

Instance data can be structured in accordance with an Application Schema defined in accordance with ISO 19109. This data can then be encoded in accordance with ISO 19118 so that it can be exchanged. Many exchange formats are possible, but the Extensible Markup Language (XML) is considered as a neutral default encoding. This encoding can be derived directly from a UML defined Application Schema in accordance with rules established in ISO/TS 19139-1. In general, XML schemas (XSD) are predefined for all of the structures modelled in the ISO/TC 211 suite of geographic information documents. However, this document (and other parts of the ISO 19144 series) do not define Application Schema. This document defines a metalanguage in which the elements used to define Application Schemas can be compared. This description is at a different level of abstraction. An XML implementation of the UML model defined in this document is not relevant. An XML schema can be implemented for an Application Schema developed using the elements described using the metalanguage.

Annex C
(informative)

Examples of the use of LCML

C.1 Descriptive examples

This annex presents a number of descriptive examples of the LCML, used to produce a Land Cover classification system and subsequently a nomenclature or Legend. Any examples are by their nature artificial and inadequate. It is not possible to show an entire Land Cover classification system or the metalanguage objects that are used to define an entire Land Cover classification system.

The process of using the LCML given in this document is to describe how a Land Cover classification system, a Legend and actual data operates at three levels of abstraction. The real or example data are an instance of a selection from a set of Legend classes. The Legend is an instance of a Land Cover classification system. The Land Cover classification system is described by the LCML, which is a set of metalanguage objects. That is, the LCML is used to create a Land Cover classification system and then specialized to add additional detail. The following examples do not show these stages of instantiation because it would make the diagrams too complex to be useful. Rather they show situations where the concepts of the LCML can be recognized in the resultant example data. The LCML concepts are general enough to support the example situations. The link back to the LCML is only by the names used in the examples. It is possible to combine elements in the LCML and describe classes in a Land Cover classification system that are very different from the basic elements of the LCML. This has been shown in some of the examples. Being a meta-language, LCML does not specify any rules for strata numeration and ordering (bottom to top, top to bottom, etc). The sequence of strata definition and position is left to the user community.

The examples are of three types. The first set of examples (C.2 to C.11) relate to the definition of specific selected Land Cover classes using the LCML. This illustrates the flexibility of the LCML to handle many different types of Land Cover.

The second set of examples (C.12 to C.16) are selected from some of the widely used Land Cover classification systems. This illustrates that these Land Cover classification systems can be represented using the LCML. Only a few classes have been shown although in some cases the complete representation of the Land Cover classification system in the LCML has been done separately and is available.

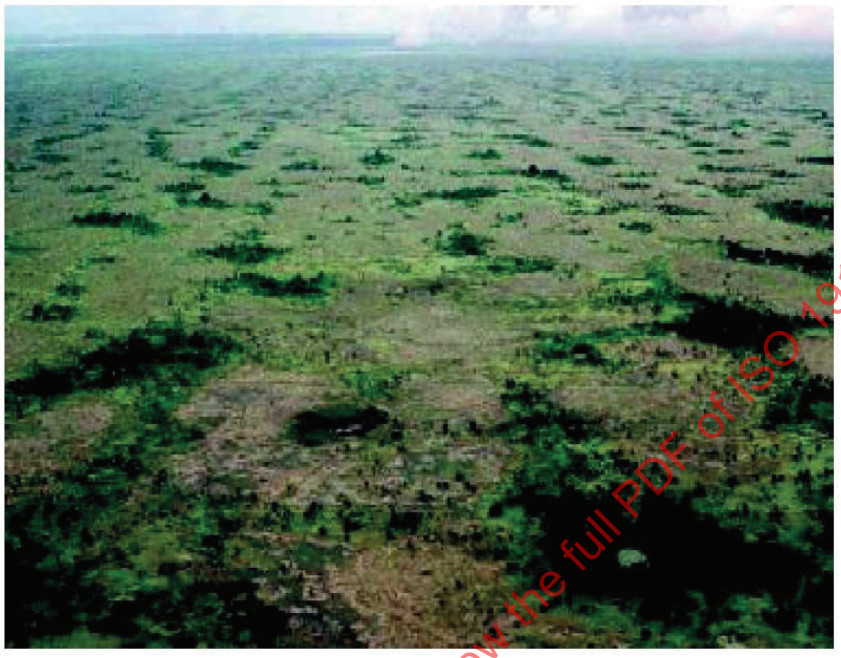
The third set of examples (C.17 to C.18) are selected from specific national large-scale Land Cover datasets and nomenclatures, such as the Land Parcel Identification System in Portugal and the Peatland Habitat Classification in Finland.

These examples are UML instance diagrams, not the class diagrams which have been used in the main body of this document. The attribute instances in all examples are shown in notes. This is done for explanatory reasons to make the values clear to the reader. Optional attributes that are not used and have defaults (where the value is the default) are not shown in the examples for simplicity. Attributes that derive from components are shown as attributes of the basic element, i.e. the attribute cover is shown as an attribute of LC_Element.

NOTE For the examples in this annex, the UML instance object names begin with the two-letter code EL to distinguish them from any other UML instance objects in the ISO/TC 211 harmonized model and to avoid any inadvertent clashes with names that can be generated in other International Standards. A detailed UML instance object -by-object description is only given in the example of a Tiger Bush (C.2), because such a detailed description for some of the other examples would be too long and would obscure the meaning of the example.

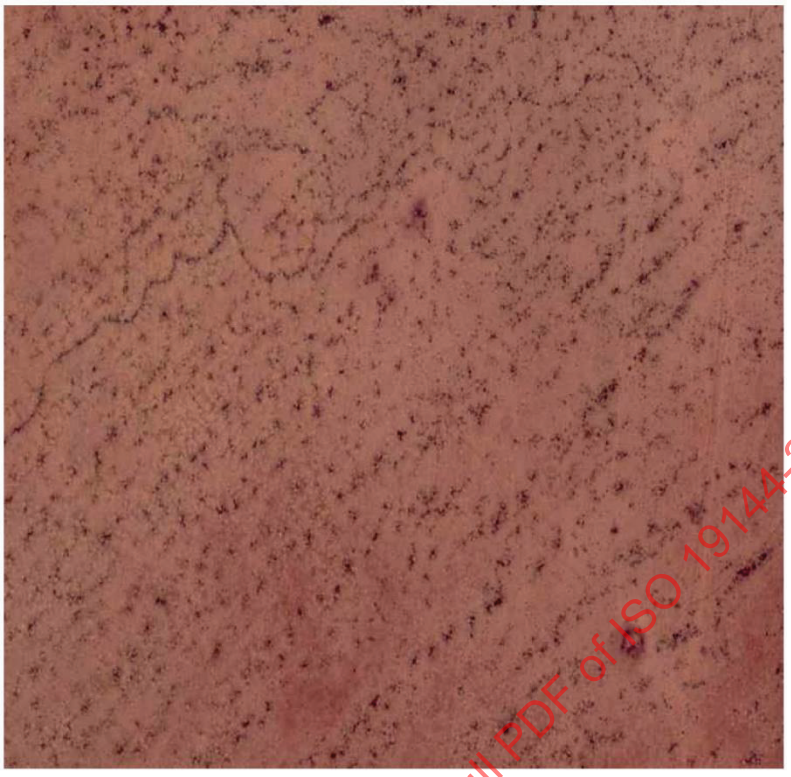
C.2 Example 1 — Example of a horizontal pattern for tiger bush

A “tiger bush” is a specific type of vegetation formation consisting of the combination of dense shrubs and open grassland in a distinct pattern. It occurs on low slopes in arid and semi-arid regions in areas such as Australia and West Africa. Figure C.1 shows an example of tiger bush in an oblique view from a plane and Figure C.2 shows an example from a satellite image. This can be treated as one Land Cover type with two horizontal patterns open shrub patches and open grassland in distinct patterns.



SOURCE Reference [56], reproduced with the permission of the authors.

Figure C.1 — Example of tiger bush — oblique view



SOURCE Reference [56], reproduced with the permission of the authors.

Figure C.2 — Example of tiger bush — satellite image

The model illustrated in Figure C.3 shows a UML instance object EL_TigerBush composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_TigerBush could represent a classification class in a particular Land Cover classification system or in a Legend Class in a particular Legend for a specific data set or data set series.

The UML instance object EL_TigerBush is an instance of LC_LandCoverClass and is composed of two separate instances of LC_HorizontalPattern, EL_HorizontalPattern_1 and EL_HorizontalPattern_2.

The first instance of EL_HorizontalPattern_1:LC_HorizontalPattern has the attribute *patternType*= elongated, *patternCoverPercentage*= the range 15.0; 25.0 %, and *patternOccurrence*= 100 % (to 100 % i.e. a range). This instance of EL_HorizontalPattern_1:LC_HorizontalPattern is composed of EL_Stratum _HP1S1:LC_Stratum. This is an instantiation of the LC_Stratum metalanguage object with the name Vegetation — shrub patches for the stratum. This instance of EL_Stratum_HP1S1:LC_Stratum has the attribute *presenceType*= Fixed, meaning that the element is not a conditional relationship. This is not shown in the model because Fixed is the default value for the attribute and absence of the attribute implies the default value. It also has the attribute *onTop*= Baseline, meaning that the element is with respect to the base level of the stratum, not on top of any other stratum. This is not shown in the model because Baseline is the default value for the attribute and absence of the attribute implies the default value. EL_Stratum_HP1S1:LC_Stratum (vegetation) is composed of EL_Shrub:LC_Shrub with the attributes *presenceType*= Fixed, (as its default value, which is therefore not shown in the model) and cover = the range 4.0 % to 20.0 %. EL_Shrub:LC_Shrub is composed of EL_Shrub:LC_NaturalOrS eminaturalVegetation which is a growth form characteristic further refining the UML instance object EL_Shrub:LC_Shrub.

The second instance of EL_HorizontalPattern_2:LC_HorizontalPattern has the attribute *patternCoveragePercentage*= the range 75.0; 85.0 %, and *patternOccurrence*= 100 %. This instance of EL_HorizontalPattern_2:LC_HorizontalPattern is composed of EL_Stratum_HP1S2:LC_Stratum which has the attribute *name*= Vegetation — open grassland and has the attribute *presenceType*= Fixed, and the attribute *onTop*= Baseline, (as the default values, which are therefore not shown in the model). EL

_Stratum_HP1S2:LC_Stratum is composed of EL_HerbaceousGrowthForm:LC_HerbaceousGrowthForm with the attributes *presenceType*= Fixed (as its default value, which is therefore not shown in the model), and *cover*= the range 15.0 % to 40.0 %. EL_HerbaceousGrowthForm:LC_HerbaceousGrowthForm is composed of EL_HerbaceousGrowthForm:LC_NaturalOrSeminaturalVegetation which is a growth form characteristic further refining the UML instance object EL_TigerBush:LC_HerbaceousGrowthForm. This is shown in Figure C.3.

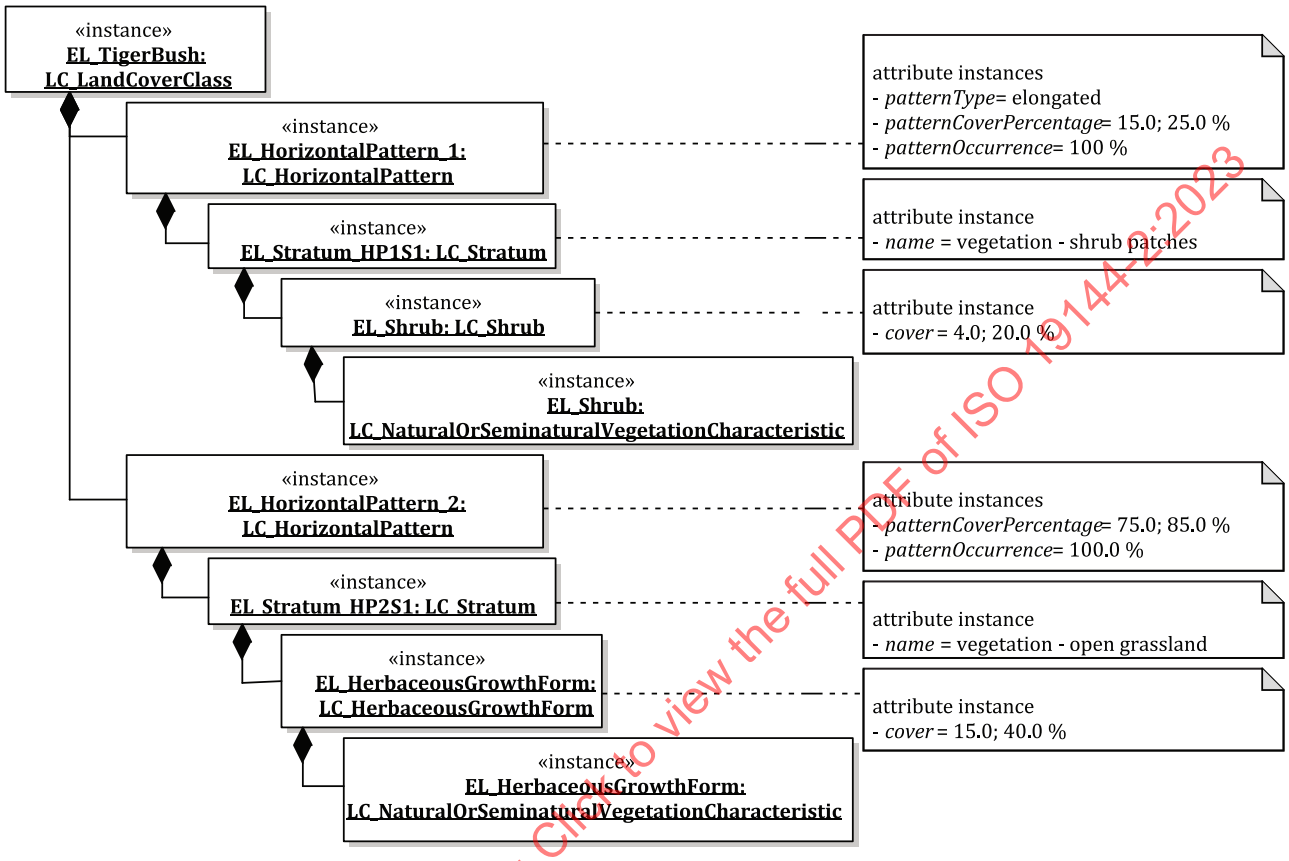


Figure C.3 — Example of tiger bush Land Cover class element composition

C.3 Example 2 — Vegetation in three strata in a tree and shrub savannah

This example describes the formation of a Land Cover class using different layers derived from instantiation of the basic Land Cover element metalanguage objects belonging to the vegetation group in the LCML. A savannah is composed by three separate layers of trees, shrubs and herbs with different cover of the woody component types. The first layer is composed by herbs. The second and third layers are composed by trees and shrubs of different height and cover (see Figure C.4).

Figure C.4 — Example of a tree and shrub savannah in three strata

The model illustrated in Figure C.5 shows a UML instance object EL_Savannah:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_Savannah:LC_LandCoverClass has been built up with a layer of herbaceous growth, a layer of trees with open cover (50 % to 100 %) and a layer of shrubs with open cover (4 % to 15 %).

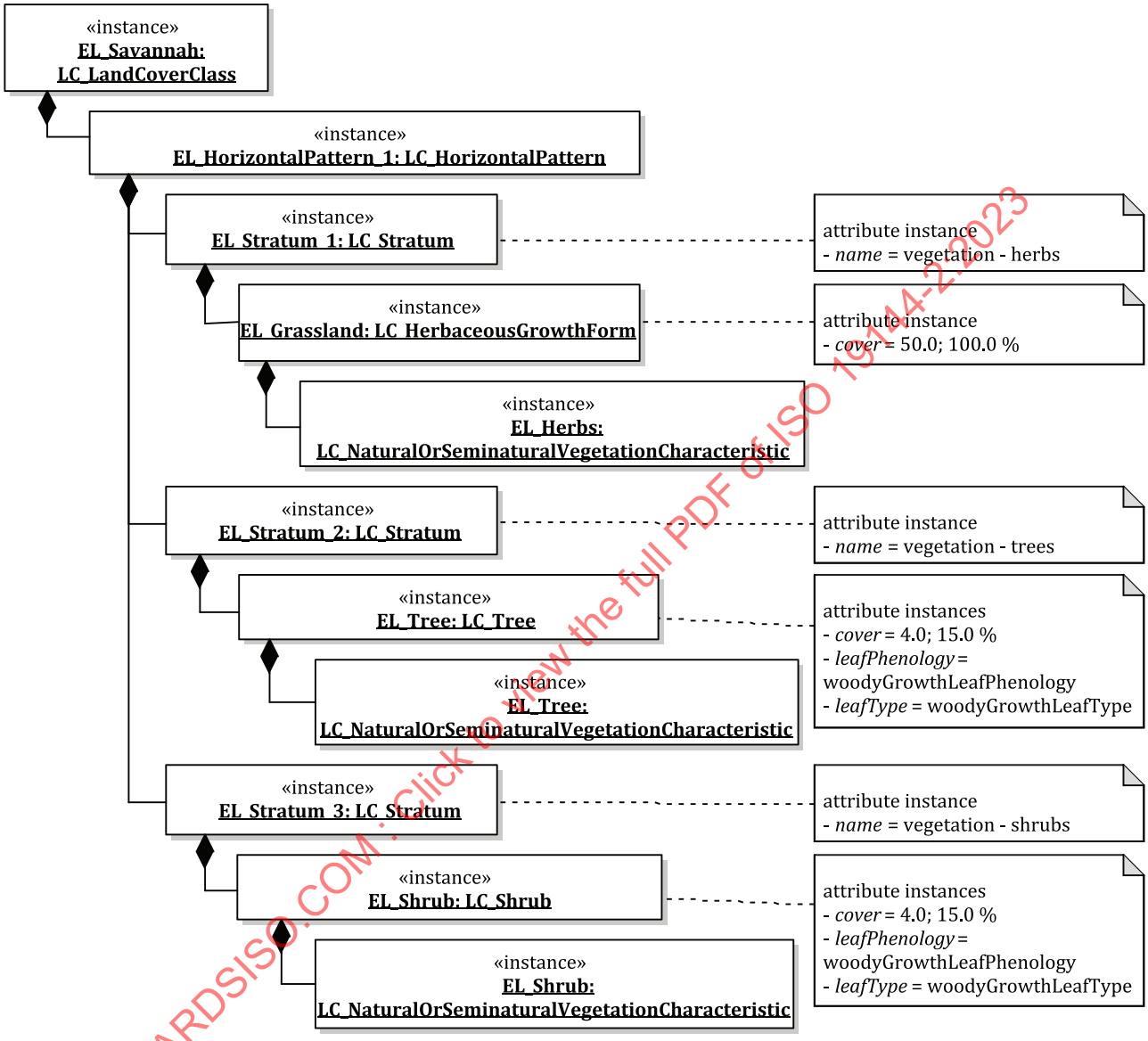


Figure C.5 — Example of a tree and shrub savannah Land Cover class element composition

C.4 Example 3 — More than one element in one stratum — Grassland with patches of course fragments

This example describes two elements within one stratum. Herbs (grassland) compete for space with patches of course fragments. The whole form a single stratum where the space occupied by both elements cannot be more than 100 %. See Figure C.6.

SOURCE Based on a portion of an image from Reference [54], reproduced with the permission of the authors.

Figure C.6 — Example of grassland with patches of coarse fragments in one stratum

The model illustrated in Figure C.7 shows a UML instance object EL_GrasslandWithCoarseFragments: LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The coarse fragments in the patches have a cover between 75 % to 80 %. The grass is very dense with a cover between 90 % to 100 %. Both of them belong to the same stratum because there is no height difference and no overlaying. Despite their relative cover, the two elements over the ground occupy a specific portion of the area not necessarily equal to their relative cover: in the example, the stone patches occupy from 30 % to 35 % while the grass occupies the 65 % to 70 % of the area. The model gives the possibility to describe the relative cover of each element (cover) and the portion that those elements occupy in the ground area (portioning).

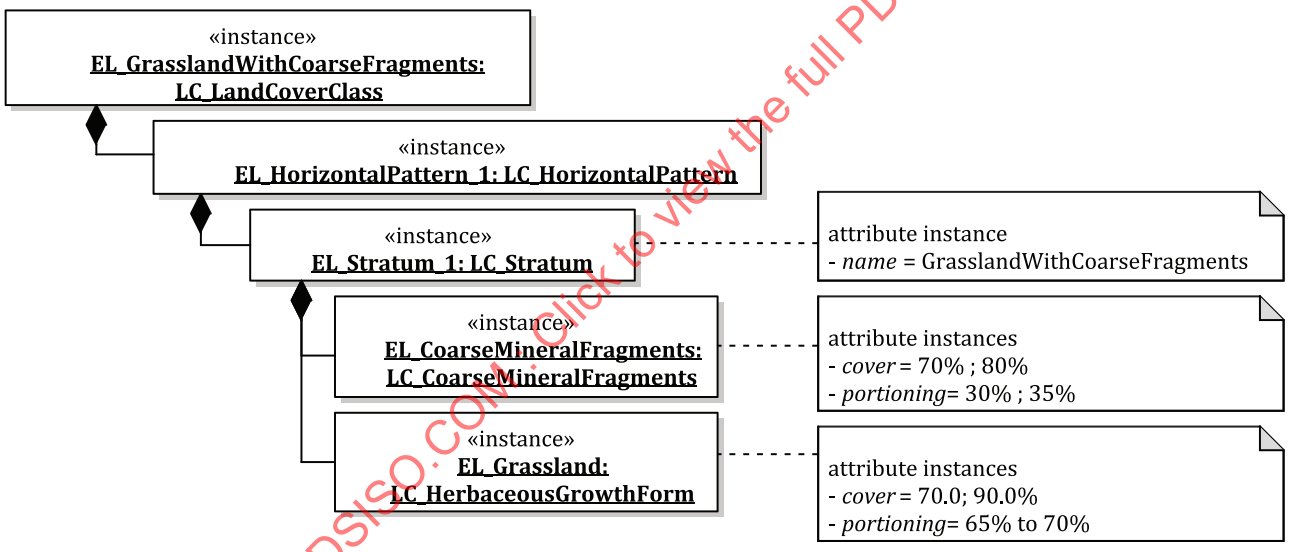


Figure C.7 — Example of grassland with patches of coarse mineral fragments Land Cover class element composition

C.5 Example 4 — Boulders with moss in a grassland

This example illustrates the “on Top” relationship in the LCML meta language. It is an example of the use of the meta language in describing an example Legend class. There are many different ways in which Boulders with Moss in a Grassland can be modelled in a Legend or schema. The way used here is the use of two different strata so that the “on Top” relationship can be shown. However, this example is to illustrate the LCML “on Top” relationship, not the different approaches to modelling Legends.

This example describes one approach of modelling boulders with moss on top of the boulders, in a grassland. Two stratums are defined for the purposes of the example. The first stratum contains the herbaceous growth form corresponding to grassland and boulders. The boulders and the grass, being in the same stratum, compete for the same space. The second stratum contains moss and includes an “onTop” relation to the second element (boulders) of the first stratum (see Figure C.8).

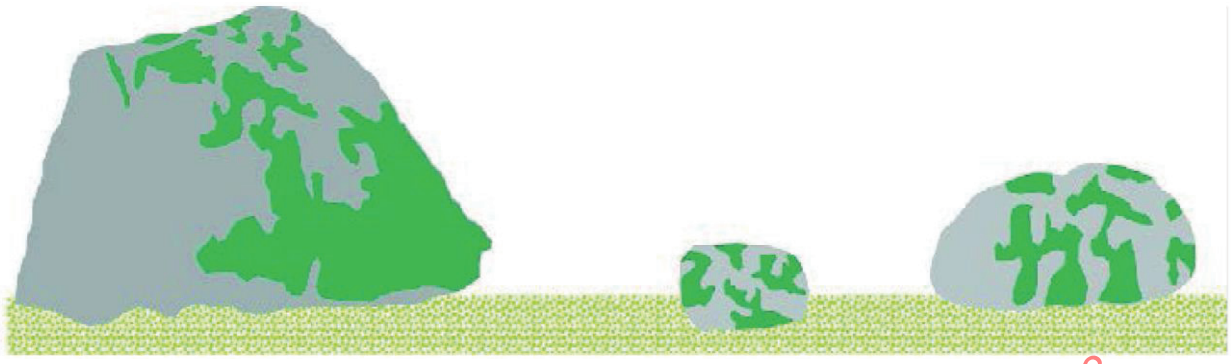


Figure C.8 — Example of boulders with moss in a Grassland

The model illustrated in Figure C.9 shows a UML instance object EL_BouldersWithMoss:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_BouldersWithMoss:LC_LandCoverClass has been built up with a layer of herbaceous growth and a layer of abiotic surface cover course fragments (Boulders) and a layer of moss with the "onTop" relation to the layer of boulders.

NOTE 1 The relationship interStrataRelationship (see 8.6.2.5) is navigable in only one direction and is 1 to 0..1 (one to one optional). This means that the UML association class can be implemented as an attribute on the instantiated instance object. This is what is shown in these examples.

NOTE 2 LC_ElementHorizontalArrangement including the *cover* attribute and LC_PlanarStrataComposition including the *strataPortioning* attribute are optional components and attributes and are not included in this example.

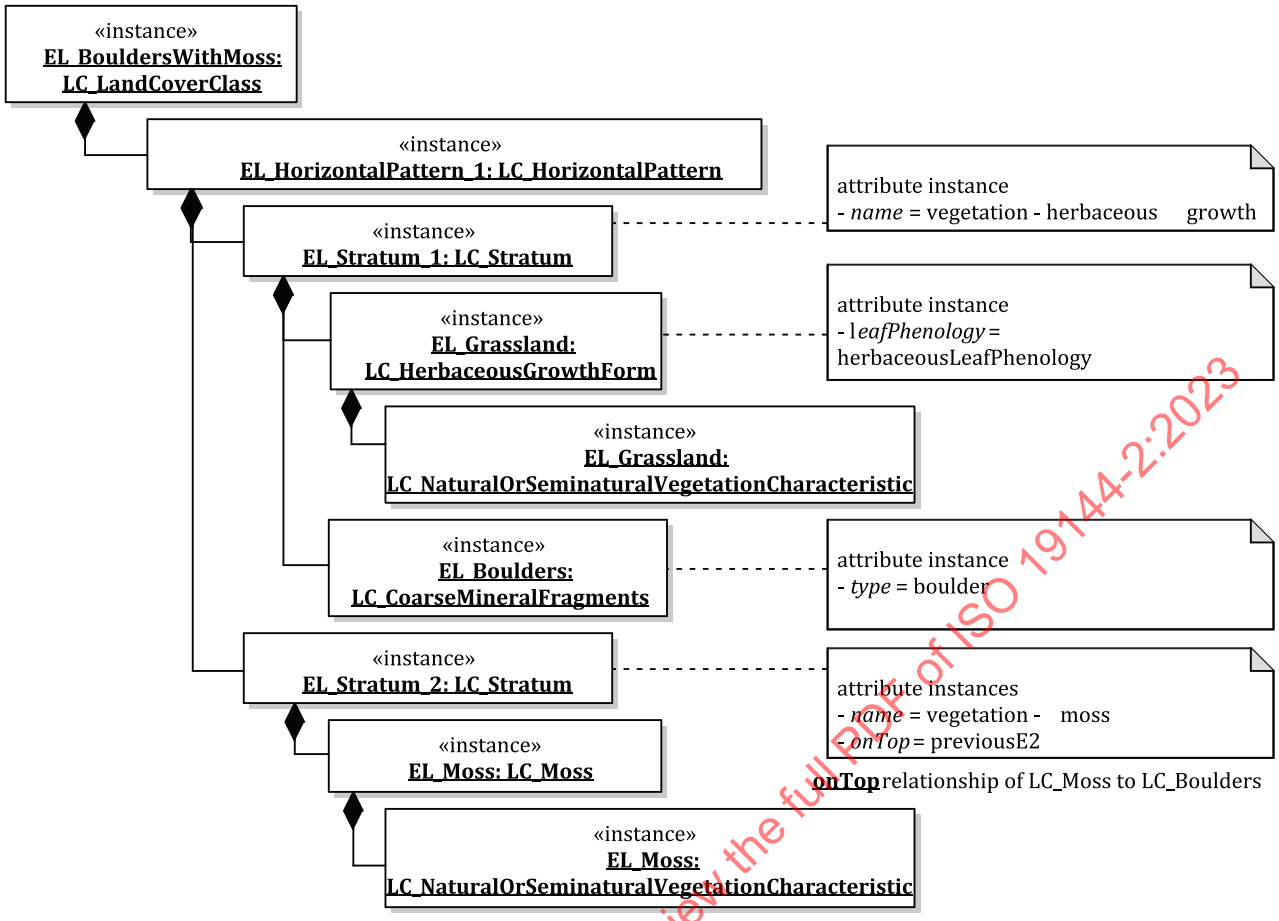


Figure C.9 — Example of boulders with moss in a grassland Land Cover class element composition

C.6 Example 5 — Mixed elements in two strata for a mangrove swamp

This example describes a mangrove swamp that consists of two separate layers, one of vegetation and the other of water. The combination of these two layers with vegetated and abiotic elements further described by their characteristics illustrates a type of "flooded or regularly flooded vegetation" without the use of complex definitions (see Figure C.10).

Figure C.10 — Example of a mangrove swamp in two strata

The model illustrated in Figure C.11 shows a UML instance object EL_Mangrove:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML

instance object EL_Mangrove:LC_LandCoverClass has been built up with a layer of trees and a water body layer.

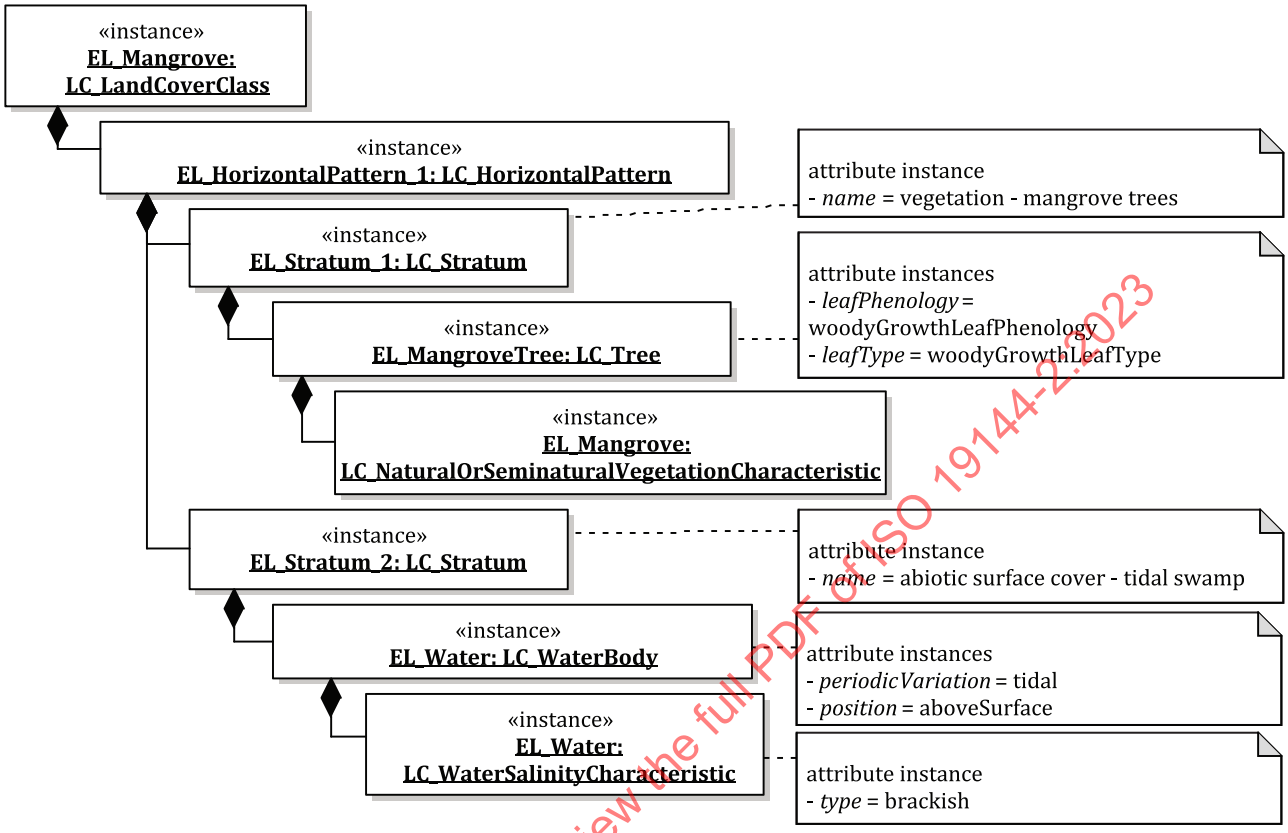


Figure C.11 — Example of a mangrove swamp Land Cover class element composition

C.7 Example 6 — Building with roof garden

This example illustrates a more complex “on Top” relationship. It describes a building with a rooftop garden. All of the vegetation layers are “onTop” of the building. This is illustrated in Figure C.12.

SOURCE Reference [62], reproduced with the permission of the authors.

Figure C.12 — Example of a building with a roof garden

The model illustrated in Figure C.13 shows a UML instance object EL_BuildingWithRoofGarden:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_BuildingWithRoofGarden:LC_LandCoverClass has been built up with the first layer representing the abiotic surface element building. A second layer of herbaceous growth is then defined with the "onTop" relation to the abiotic surface layer containing the building. This puts the herbaceous growth form on top of the building. The third layer is of trees. Each of these are also on top of the building. For simplicity, limited attributes have been defined to characterize the elements in this example.

This is an example of Land Cover. A building is a physical thing on the land and is Land Cover. A building can be attributed with respect to its use as part of a Land Use description. There is no Land Use attribution of the building in this example.

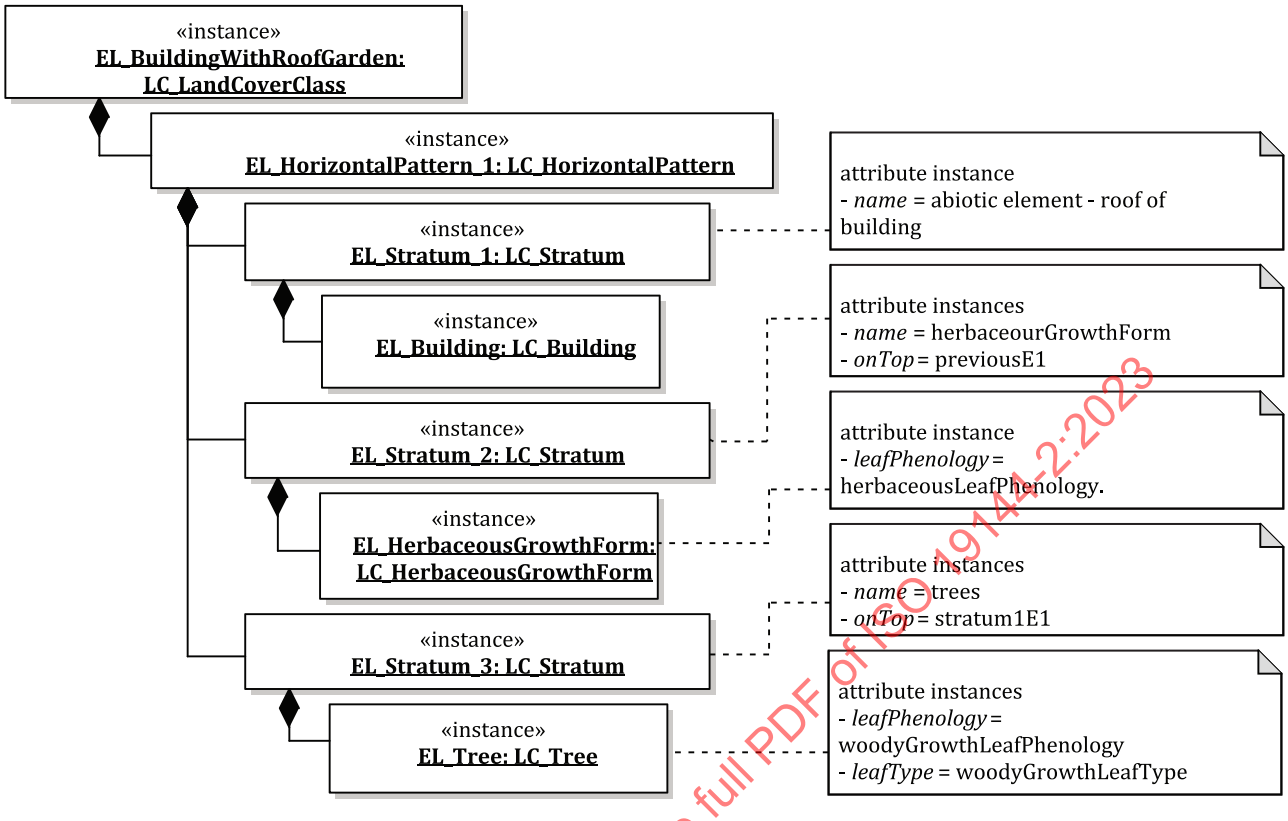


Figure C.13 — Example of building with roof garden Land Cover class element composition

C.8 Example 7 — Boreal and hemi-boreal forest

This example describes a boreal and hemi-boreal forest system where the tree layer is in two different heights. The trees are in two parts, the overstorey trees and the understorey trees, and a separate shrub layer and forbs layer. The example shows two layers of natural trees. In this example there is intentionally no height, cover or leaf type/leaf phenology attribution in order to remain very general. A third layer of shrubs and a fourth layer of forbs are described. An addition element describing the climatic area could have been added but is not included in the example for simplicity. This is illustrated in Figure C.14

SOURCE Reference [55], reproduced with the permission of the authors.

Figure C.14 — Example of a boreal/hemi-boreal forest

The model illustrated in Figure C.15 shows a UML instance object EL_BorealAndHemiborealForest:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_BorealAndHemiborealForest:LC_LandCoverClass has been built up with four vegetation layers consisting of two layers of trees, a layer of shrubs and a layer of forbs. This example has been kept very simple and no attributes have been used to characterize the trees, shrubs or forbs.

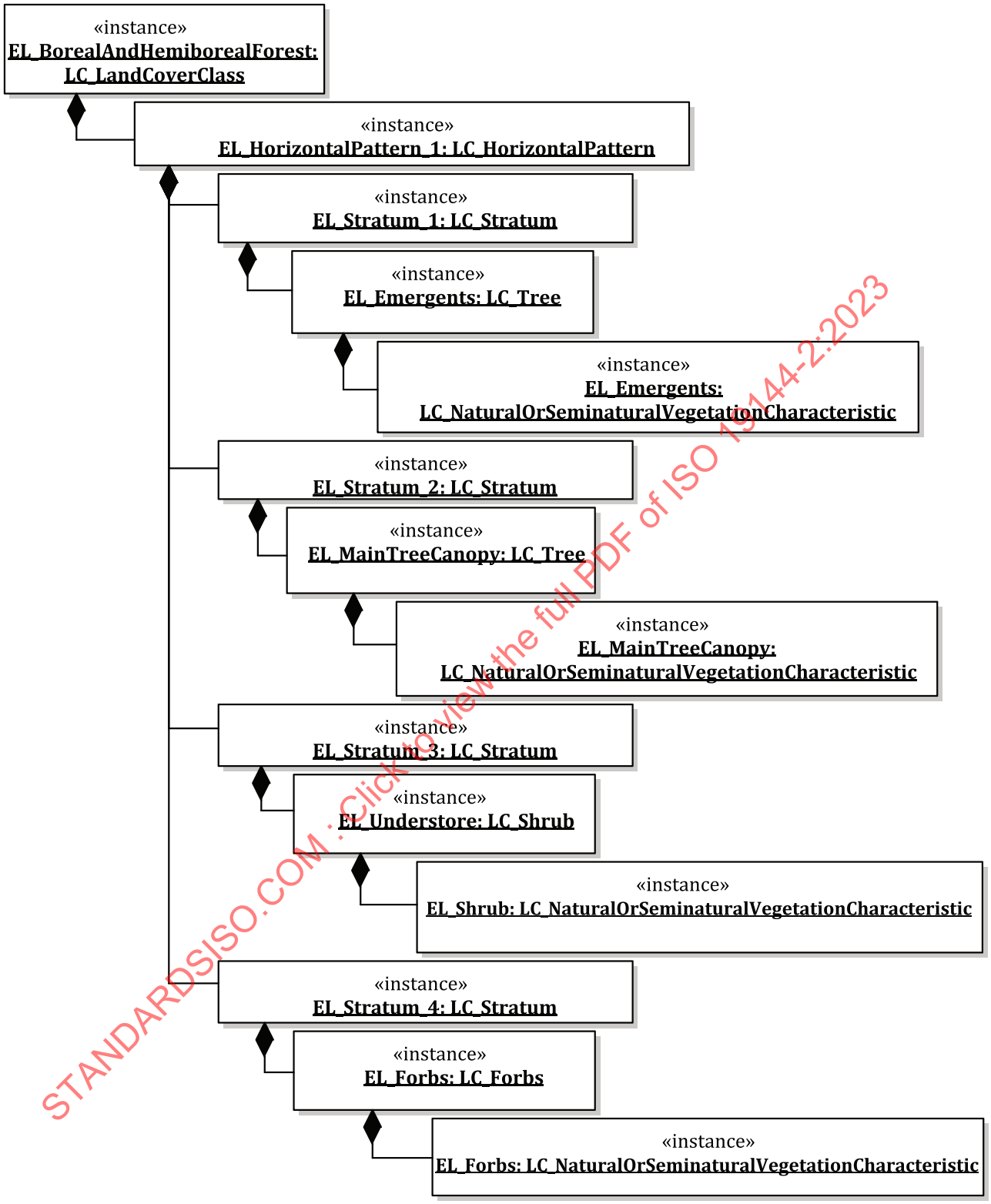


Figure C.15 — Example of a boreal and hemi-boreal forest in four strata Land Cover class element composition

C.9 Example 8 — Vegetation in multiple strata for a Hagemarklandscape

A Hagemarklandscape ("garden-field-landscape") is either a forest that is intensively used as a pasture or a pasture with a large number of scattered trees. The use as pasture has changed the ground

vegetation considerably. Bush and shrub are usually absent and the grasses and herbs now consist of those species that benefit from grazing and can resist the trampling of the animals. Most branches on the trees have been removed (by the grazing animals) from the lower part of the stems of the trees. The vegetation type therefore resembles a kind of park landscape (see Figure C.16).

SOURCE Reference [65], reproduced with the permission of the authors.

Figure C.16 — Example of a Hagemarklandscape

The model illustrated in Figure C.17 shows a UML instance object EL_Hagemarklandscape:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_Hagemarklandscape:LC_LandCoverClass has been built up with a layer of trees with open cover (20 % to 40 %) grazed in the lower branches (intensity of grazing 10 % to 30 %) and a layer of grass intensely grazed (intensity of grazing 70 % to 90 %). In this case grazing is occurring by several types of wild and domesticated animals on the grasses and on the leaves of the lower branches of the trees. This type of "grazing" of the lower branches of trees is sometimes called "browsing". The LC_GrazedCharacteristic addresses only the physiognomic appearance of grazed land. For a description of the Land Use activity of grazing, see ISO/TS 19144-3.

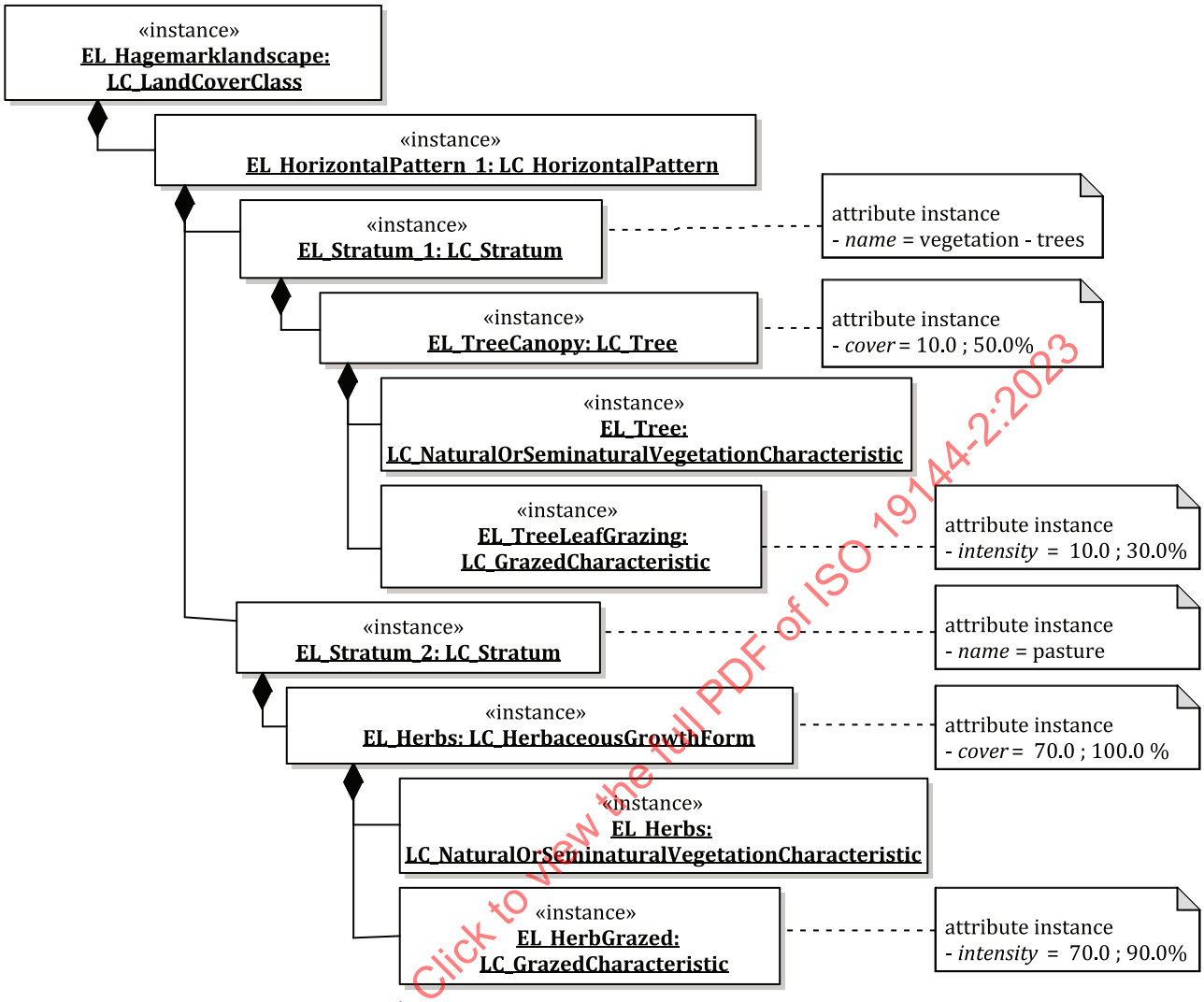


Figure C.17 — Example of a Hagemarklandscape Land Cover class element composition

C.10 Example 9 — Bare field planted with wheat same year

This example illustrates a temporal relationship. It describes bare fields that are planted with wheat. That is, for part of the year the fields are bare and for part of the year they are covered by wheat. This is described by the use of a sequential temporal relationship between the two elements bare soil and graminoid vegetation, that is characterized as cultivated and managed vegetation with a floristic aspect species, "Wheat". This is shown in Figure C.18.

The instance model illustrated in Figure C.19 shows a UML instance object EL_BareFieldsPlanted WithWheat:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The UML instance object EL_BareFieldsPlantedWithWheat:LC_LandCoverClass has been built up with one Stratum that has two elements EL_BareSoil and EL_Graminoids. The metalanguage instance EL_Graminoids is characterized by EL_CultivatedAndManagedVegetation and by EL_FloristicAspect with EL_FloristicAspectSpecis (Wheat).

NOTE The relationship interStrataRelationship (see 8.6.2.5) is navigable in only one direction and is 1 to 0..1 (one to one optional). This means that the UML association class can be implemented as an attribute on the instantiated object. This is what is shown in these examples. This example only contains information about the length of time, not which months.

SOURCE Reference [54], reproduced with the permission of the authors.

Figure C.18 — Example of a bare field planted with wheat same year

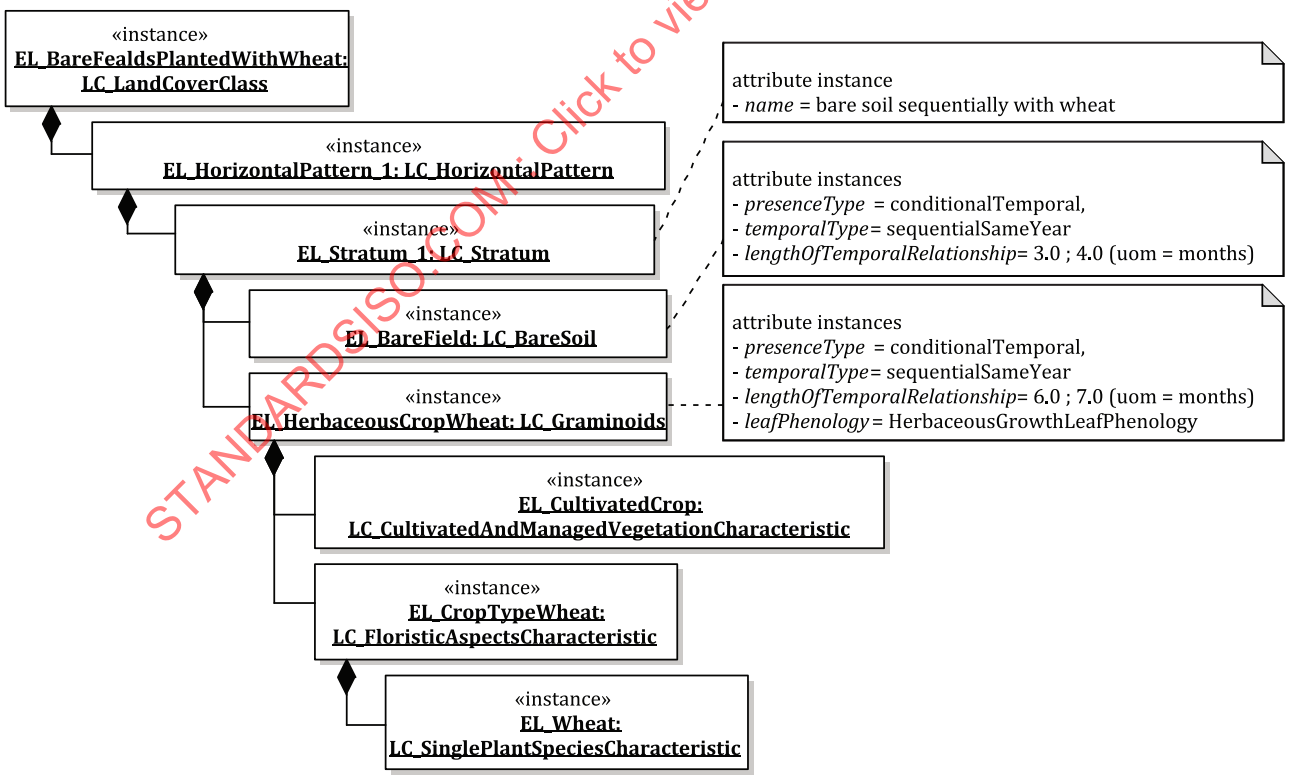


Figure C.19 — Example of a bare field planted with wheat same year Land Cover class element composition

C.11 Example 10 — Greenhouse

This example shows an area which is covered by a greenhouse building. The LCML does not include an attribute for identifying a building as being of type “greenhouse”. The use of the building can be defined in a Land Use description (see ISO/TS 19144-3).

Without knowing what the use of the building is, the appearance of the building can be described as part of Land Cover. This is a purely physiognomonic description of what the building looks like. A greenhouse is shown in Figure C.20.

The instance model illustrated in Figure C.21 shows that two layers are used, composed by the LCML elements LC_HerbaceousGrowthForm and LC_Building. What is described here is vegetation within a building. Both the building and the vegetation are from the same base. Stratum_1 is the vegetation which in this example is Herbaceous Growth Form. Stratum_2 is the building made of light material, in this case plastic. The vegetation is entirely within the building, so if viewed from above, all that can be seen is the building. Therefore, the *strataPortioning* for the vegetation is 0 % (it can't be seen from above) and 100 % for the building. The LCML element LC_Building has three properties: *constructionMaterial* (Light Material), *horizontalArrangement: cover* (from 100 %) and *height* (from 4,0 m to 8,0 m). The LCML element LC_HerbaceousGrowthForm has two properties: *cultivatedAndManaged* and *irrigated*.

SOURCE *Reference* [54], reproduced with the permission of the authors.

Figure C.20 — Example of a greenhouse

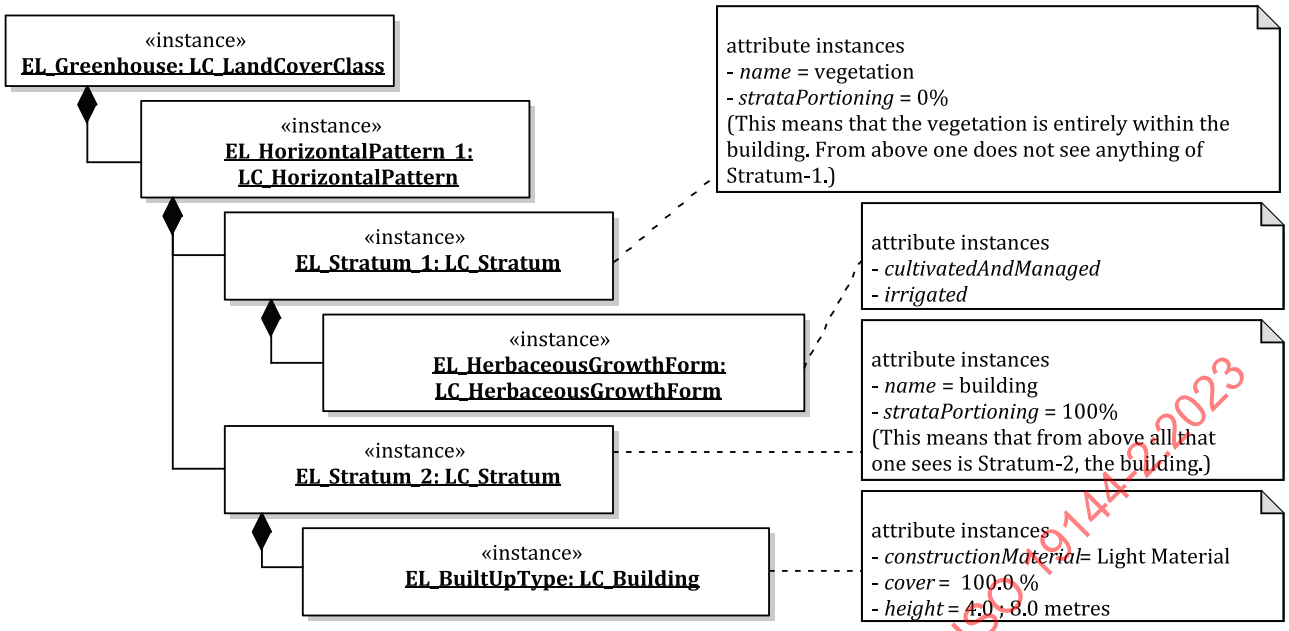


Figure C.21 — Example of greenhouse

C.12 Example 11 — Example CORINE class 311 Broad-leaved Forests

This example is a translation of a Legend class from the CORINE Land Cover classification system. The CORINE description is:

"*vegetation formation composed principally of trees, including shrub and bush understoreys, where broad-leaved species predominate.*

The predominant classifying parameter for this class is a crown cover density of > 30 % or a minimum 500 subjects/ha density, with broad-leaved trees representing > 75 % of the formation. The minimum tree height is 5 m."[12]

The LCML representation illustrated here refers to the specific textual definition given above, and is not necessarily directly applicable to successive CORINE refinements. An illustration of Land Cover that can be described by this class is provided in Figure C.22.

The model illustrated in Figure C.23 shows that two layers are used. The first layer is composed by the LCML element Tree (with a characteristic Natural or Seminatural). The LCML element Tree has two properties: Cover (from 30 % to 100 %) and Broad-leaved with the percentage of cover from 75 % to 100 % to correctly formulate the concept of predominant broad-leaved species. The second layer is composed by the LCML element Shrub (with a characteristic Natural or Seminatural). While the first layer is always present ("Fixed"), the second one can exist or not ("Optional").

SOURCE Reference [54], reproduced with the permission of the authors.

Figure C.22 — Example of CORINE broad-leaved forest Land Cover class

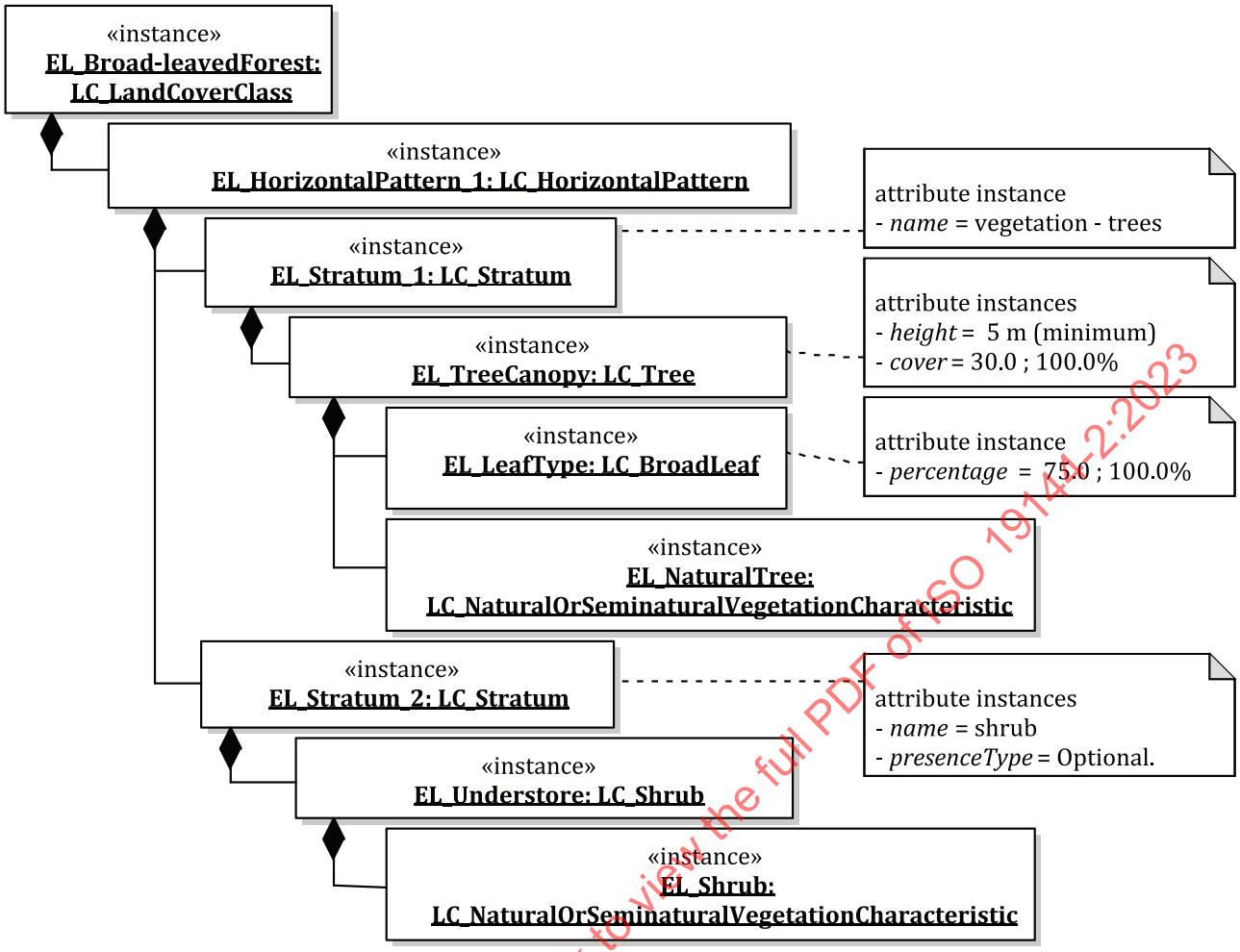


Figure C.23 — Example of CORINE froad-leaved Forest Land Cover class element composition

C.13 Example 12 — Example CORINE class 111 continuous urban area(s)

This example is a translation of a Legend class from the CORINE Land Cover classification system. This example is based on the original textual description of the CORINE class as described in 1985. The LCML representation illustrated here refers to the specific textual definition given below, and is not necessarily directly applicable to successive CORINE refinements.

The CORINE description is:

"*urban structures and transport networks are dominating the surface area. > 80 % of the land surface is covered by impermeable features like buildings, roads and artificially surfaced areas. Non-linear areas of vegetation and bare soil are exceptional.*"[12]

An illustration of Land Cover that can be described by this class is illustrated in Figure C.24.

The model illustrated in Figure C.25 shows that two horizontal patterns have been applied one with the LCML element Non-Linear Surface and the other with the LCML element Linear Surface. The use of two Horizontal Patterns implies that this combination of non-linear and linear elements is for a "unicum" that will be expressed in the same way at any scale used.

SOURCE Reference [54], reproduced with the permission of the authors.

Figure C.24 — Example of CORINE continuous urban area Land Cover class

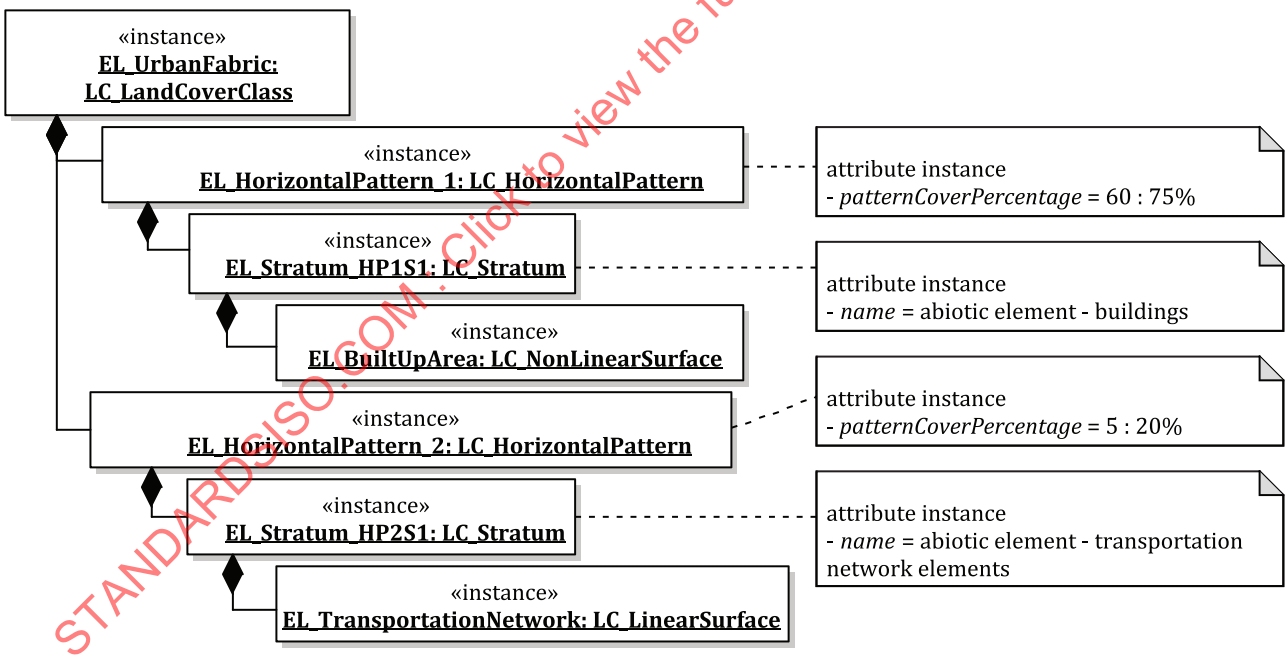


Figure C.25 — Example of CORINE continuous urban area Land Cover class element composition

C.14 Example 13 — Example CORINE class 244 agro-forestry area(s)

This example is a translation of a Legend class from the CORINE Land Cover classification system. The CORINE description is:

"*annual crops or grazing land under the wooded cover of forest species.*"[12]

This LCML description is of this textually defined Legend class, not of any more recent refinement. An illustration of Land Cover that can be described by this class is illustrated in Figure C.26.

The model illustrated in Figure C.27 shows that two layers are used. The first one is composed by either the LCML element Herbaceous Vegetation (with an extra characteristic Cultivated which comes from LC_GrowthFormCharacteristic) or the LCML element Herbaceous Vegetation (with an extra characteristic Grazed which comes from LC_GrowthFormCharacteristic). The second one is composed by the LCML element Tree. The cover of the trees is not indicated in the CORINE class description. However, it has been interpreted in the translation as a rather open layer (cover between 5 % to 30 %). In LCML the user can avoid specifying the property Cover.

SOURCE Reference [54], reproduced with the permission of the authors.

Figure C.26 — Example of CORINE agro-forestry area Land Cover class (showing grazed land)

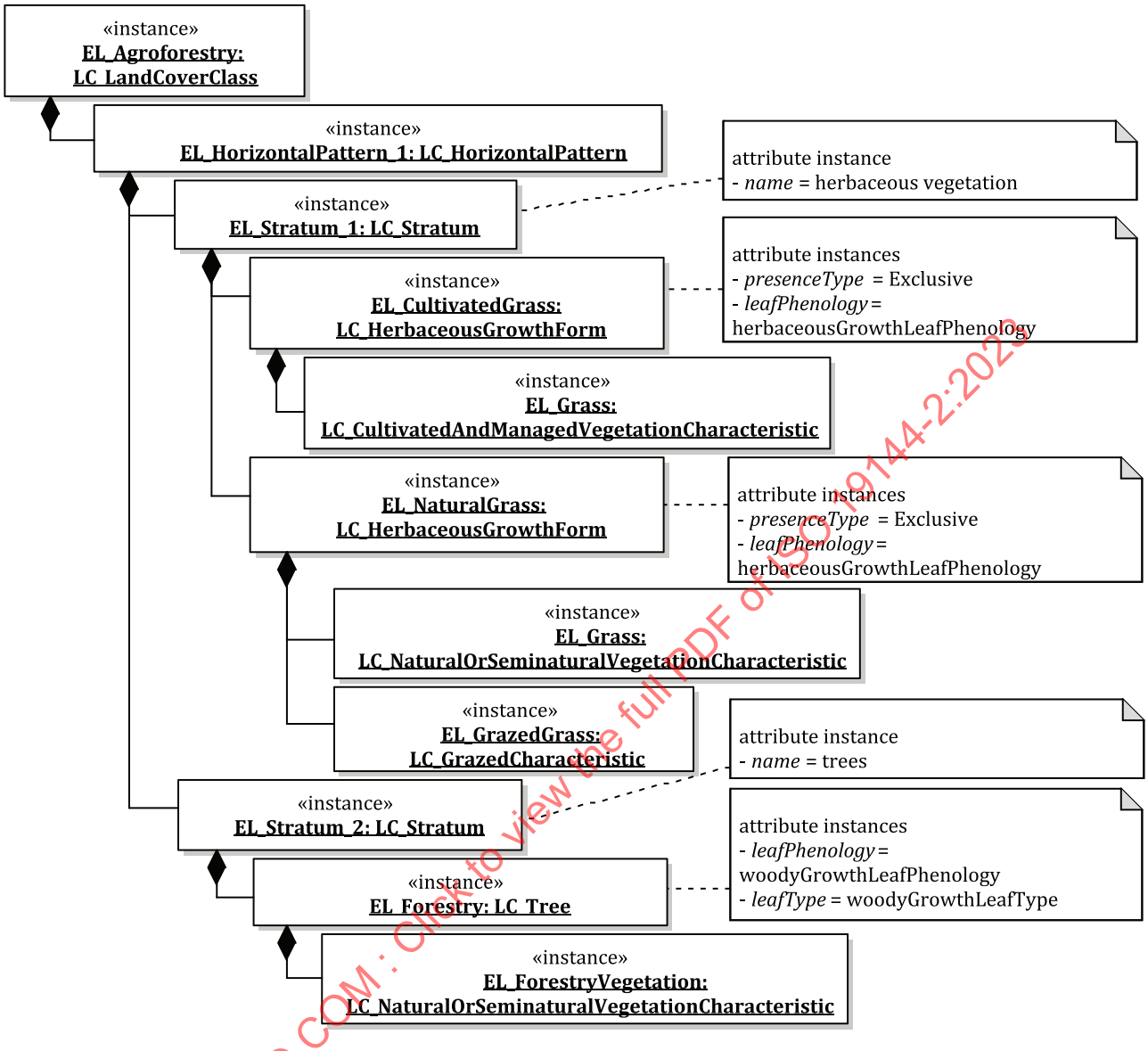


Figure C.27 — Example of CORINE Agro-Forestry Area Land Cover class element composition

C.15 Example 14 — Example evergreen forest land (Anderson)

This example is a translation of a Legend class from the Anderson (USGS) Land Cover classification system. The Anderson description is:

"*evergreen forest land includes all forested areas in which the trees are predominantly those which remain green throughout the year. Both coniferous and broadleaved evergreens are included in this category.*"[7]

This LCML description is of this textually defined Legend class. An illustration of Land Cover that can be described by this class is illustrated in Figure C.28.

The instance model illustrated in Figure C.29 shows that one layer is composed by the LCML element Tree (with an extra characteristic Natural). The LCML element Tree has two properties: Cover (from 30 % to 100 %) and Evergreen.

SOURCE Reference [54], reproduced with the permission of the authors.

Figure C.28 — Example of evergreen forest land (Anderson) Land Cover class

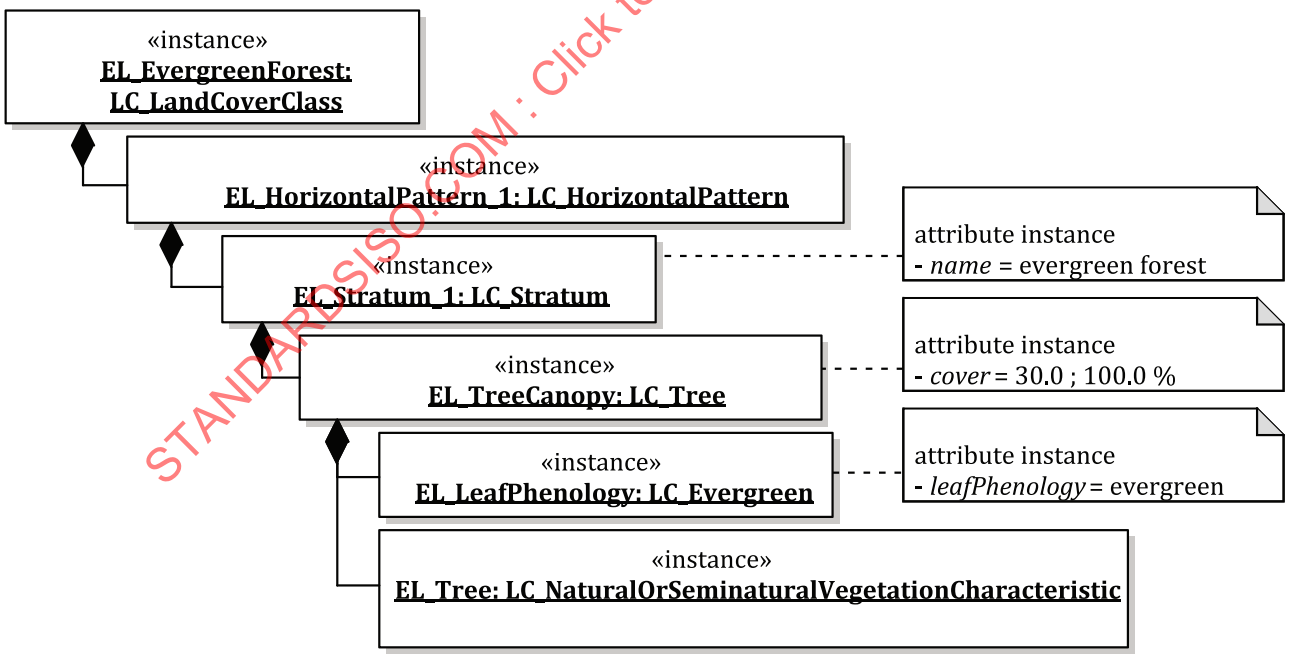


Figure C.29 — Example of evergreen forest land (Anderson) Land Cover class element composition

C.16 Example 15 — Example herbaceous with sparse tree/shrub (Global Map)

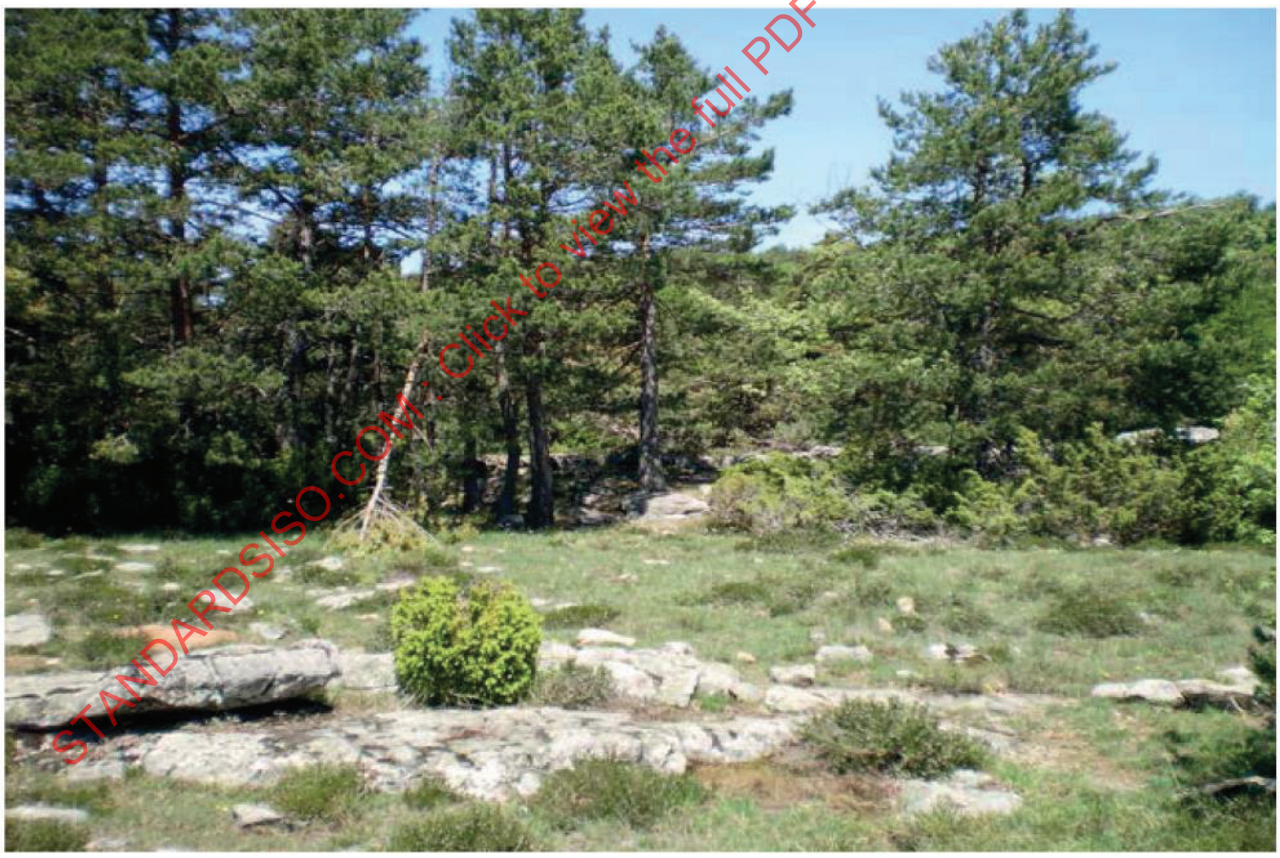
This example is a translation of a Legend class from the Global Map Land Cover classification system. Global Map has adopted the UN FAO LCCS standard.[43] The definition of the Legend class is the following:

"*the main layer consists of herbaceous vegetation from closed to open, the second and third layers are composed by sparse trees and sparse shrubs*".[25],[44]

This LCML description is of this textually defined Legend class. An illustration of Land Cover that can be described by this class is illustrated in Figure C.30.

NOTE Global Map is a digital geographic dataset including Land Cover data of the whole globe, developed with unified specifications, through international cooperation among National Mapping Organizations of the world.

The model illustrated in Figure C.31 shows that three separate layers are used. The first layer is composed of the LCML element Herbaceous (with an extra characteristic Natural). The LCML element Herbaceous has one property, Cover (from 15 % to 100 %). The second layer is composed by the LCML element Tree (with an extra characteristic Natural). The LCML element Tree has a property Cover (from 1 % to 15 %). The third layer is composed by the LCML element Shrub (with an extra characteristic Natural). The LCML element Shrub has a property Cover (from 1 % to 15 %).



SOURCE Reference [54], reproduced with the permission of the authors.

Figure C.30 — Example of herbaceous with sparse tree/shrub (Global Map) Land Cover class

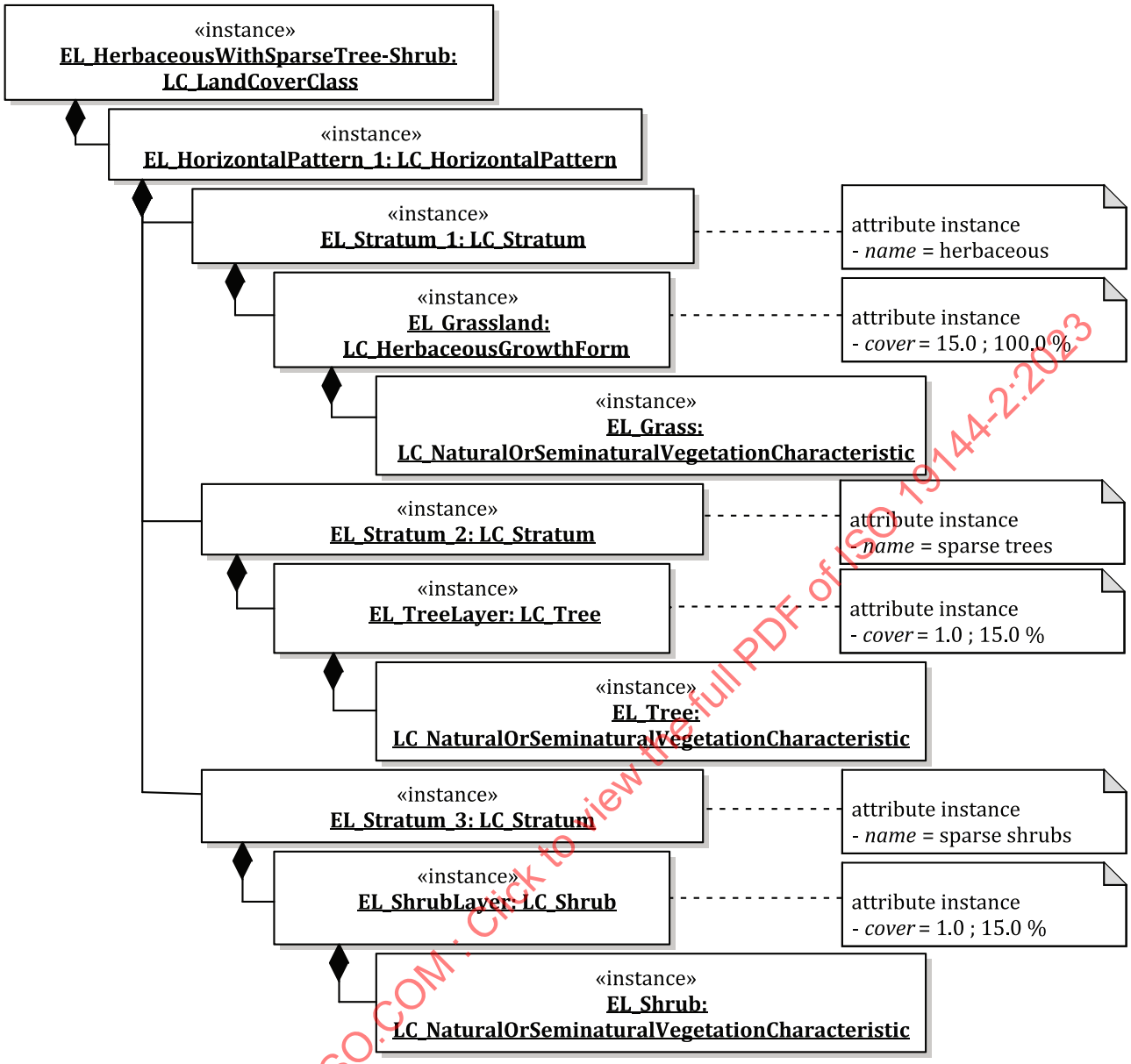


Figure C.31 — Example of Herbaceous with sparse tree/shrub (Global Map) Land Cover class element composition

C.17 Example 16 — Example of complex agricultural Land Cover (pro-rata grassland) Montado

An example of complex agricultural Land Cover class related to agroforestry, as recorded in the Land Parcel Identification System (LPIS) of Portugal, is shown in Figure C.32. The possible presence of sporadic shrubs is considered marginal and not accounted. The class encompasses semi-natural grasslands with open to dense patches of oak trees. The patches of herbaceous and woody plants form an intrinsic mix, perceived as "unicum", irrespective of the applied cartographic scale. It can be regarded as a single entity from the functional point of view, representing a silvo-pasture and called "montado". In the national LPISnomenclature the class description is:

"*Woodland with Open Medium to Tall Herbaceous Layer. Floristic Aspect: Cork Oak or Holm Oak or Pyrenean Oak. At least 60 % of the parcel tree cover is Quercus. Cork Oak density is minimum 40 trees per hectare/ Holm Oak or Pyrenean Oak density is minimum 60 trees per hectare.*" [49],[50]

This example makes the simplification of assuming all the tree cover is Oak (Quercus).

In such grasslands with open to dense trees, the vegetation located beneath the trees is subject to different agronomic practices and is thus accounted separately for the quantification of the effective grazed area. This grassland could also have different plant variety and composition and thus performs differently with respect to environment and climate.

SOURCE Reference [63], reproduced with the permission of the authors.

Figure C.32 — Typical grassland with oak trees, forming sylvo-pastoralsystem, called "Montado"

To model such Land Cover classes in LCML, the tegon[15][30] concept developed by the Joint Research Center of the European Commission is used. The concept is applied in use cases, such as the European Union Common Agricultural Policy and European Territorial Co-operation Programme. It treats the agro-forestry class as representing an intrinsic mix of 3-dimensional elementary biophysical features (tegons) having different number of strata. In the case of grassland with trees, there are two types of biophysical features:

1) the first one having only one stratum with one LC element of herbaceous vegetation (grasses); and

2) the second having one stratum with one LC element of herbaceous vegetation (grasses) and another one above with one LC element of woody vegetation (trees).

The presence, abundance and horizontal composition of these two types of physical features is managed in LCML through the LC_HorizontalPattern object.

Figure C.33 is an illustration of the approach of using horizontal pattern and strata. It shows grass with scattered patches of trees. The portion of the grass beneath the trees has different plant composition and characteristics (density, height).

Figure C.33 — Use of horizontal pattern and strata

The grass with trees and grass without trees are treated as separate physical features composed by 3-dimensional elementary features (tegons). This results in an intrinsic (functional entity) mix between two types of Land Cover features having different strata. This is illustrated in Figure C.34.

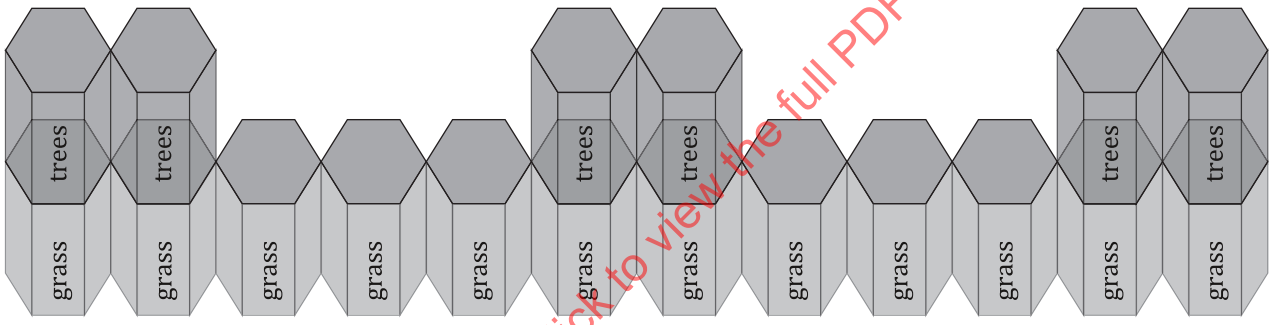


Figure C.34 — Tegon representation

Figure C.35 shows how this structure is described in LCML with the "horizontal pattern".

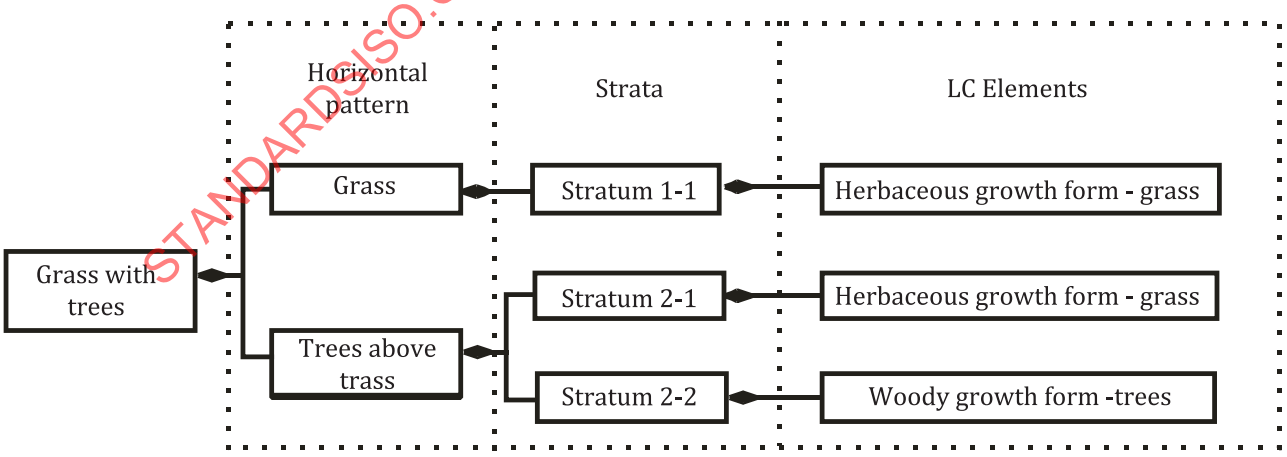


Figure C.35 — LCML representation

The model illustrated in Figure C.36 shows the Land Cover class element composition.

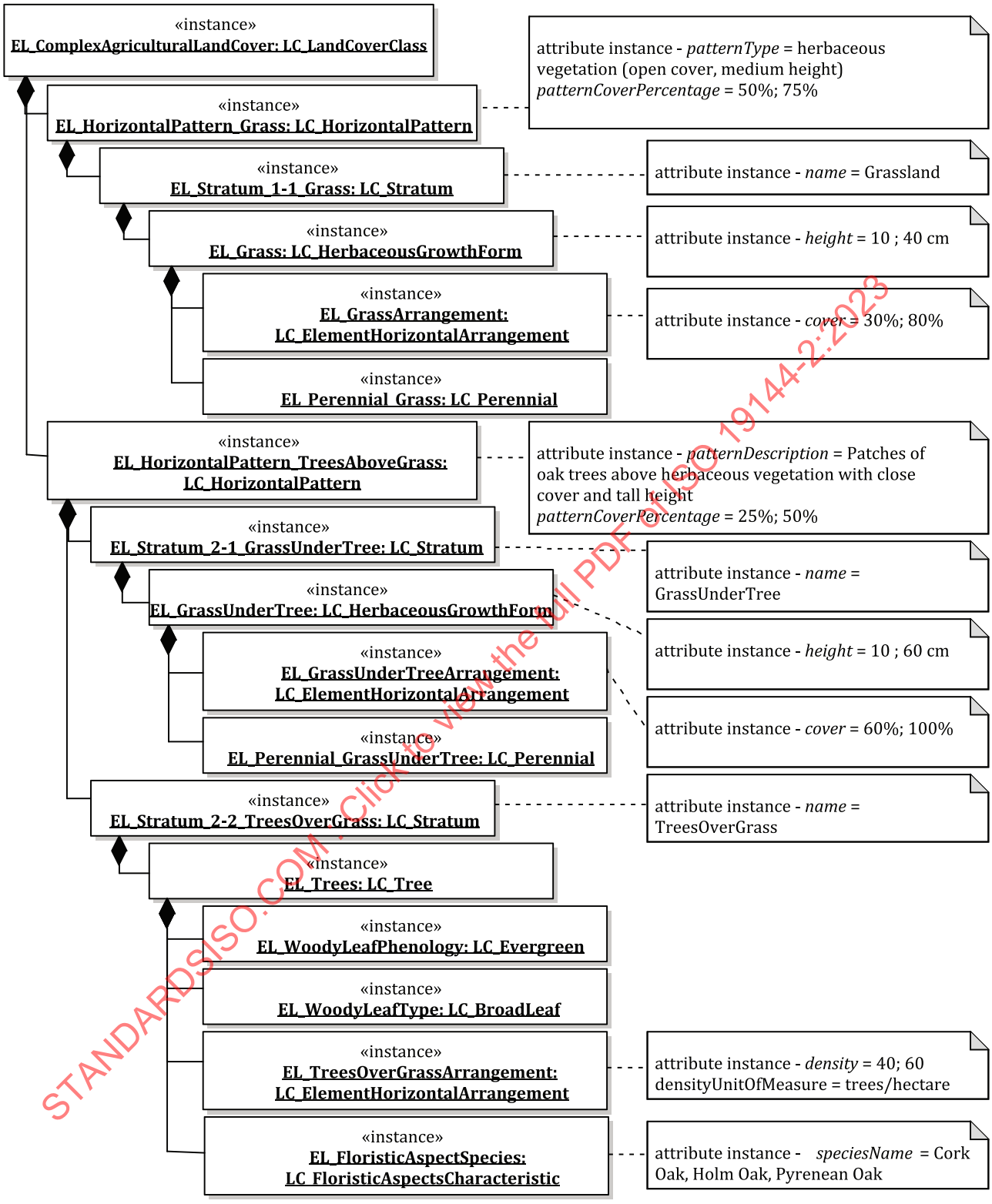


Figure C.36 — Example of complex agricultural Land Cover class element composition

C.18 Example 17 — Example of wooded peatland (mire with trees)

This is an example of peatland with openly and uniformly distributed trees and occasional shrubs, belonging to a class “Spruce Mire” in the Finnish peatland habitat classification.[29][31] The mire consists of organic layer, saturated with water. There are patches of water appearing at the surface.

The dominant tree species are evergreen, such as the spruce, though deciduous trees can also grow abundantly in spruce mires that are richer in nutrients. The presence of living and dead trees of different sizes and ages is an important structural feature (Figure C.37). The ground layer consists of grasses and herbaceous plants or sphagnum mosses. In nutrient-poor spruce mires, dwarf shrubs can be present. Wetland and peatland are another Land Cover category where it is essential to account for the relationship between LC elements in different strata. This is particularly valid for peatland forests, where there the accumulation on the topsoil layer of dead organic material (litter) is directly related with the trees present above. In the Nordic European countries, peatlands could have several strata of vegetation. Some of them could be occasionally present in the given class instances. The semantics applied in wetland class descriptions are extensively studied within the project SEPLA[27],[51] (Satellite based mapping and monitoring of European peatland and wetland for LULUCF[52] and agriculture) developed under the work program between JRC (Joint Research Centre) and DG Clima of the European Commission.

SOURCE Reference [53], reproduced with the permission of the authors.

Figure C.37 — Example of mire with trees in Nuuksio National Park, Finland

As in the previous example, the given peatland class could be described in LCML through the principles of tegon and applying the functional entity approach, based on the LC_HorizontalPattern object. However, the spread of the tree is relatively uniform and not necessarily clustered. There is also a canopy effect of the trees over the layer of grass or sphagnum mosses. In this respect, the peatland could be modelled through the strata composition alone. A combination of LC elements related to organic deposits and water are present in Stratum 1. Stratum 2 holding the grasses and mosses has the attribute *onTop* of LC_InterStrataRelationship set to PreviousE1 which means that the elements of the stratum are “on top” of the first element of the previous stratum, to account for the explicit relation of the vegetation with the organic layer beneath. For Stratum 3 holding occasional shrubs, the stratumPresenceType is

set to optional to account for their possible presence in the class instances. In the uppermost stratum 4, there are evergreen and deciduous trees competing for the same space. Most of the deciduous trees have “dead status”.

The model illustrated in Figure C.38 shows the Land Cover class element composition.

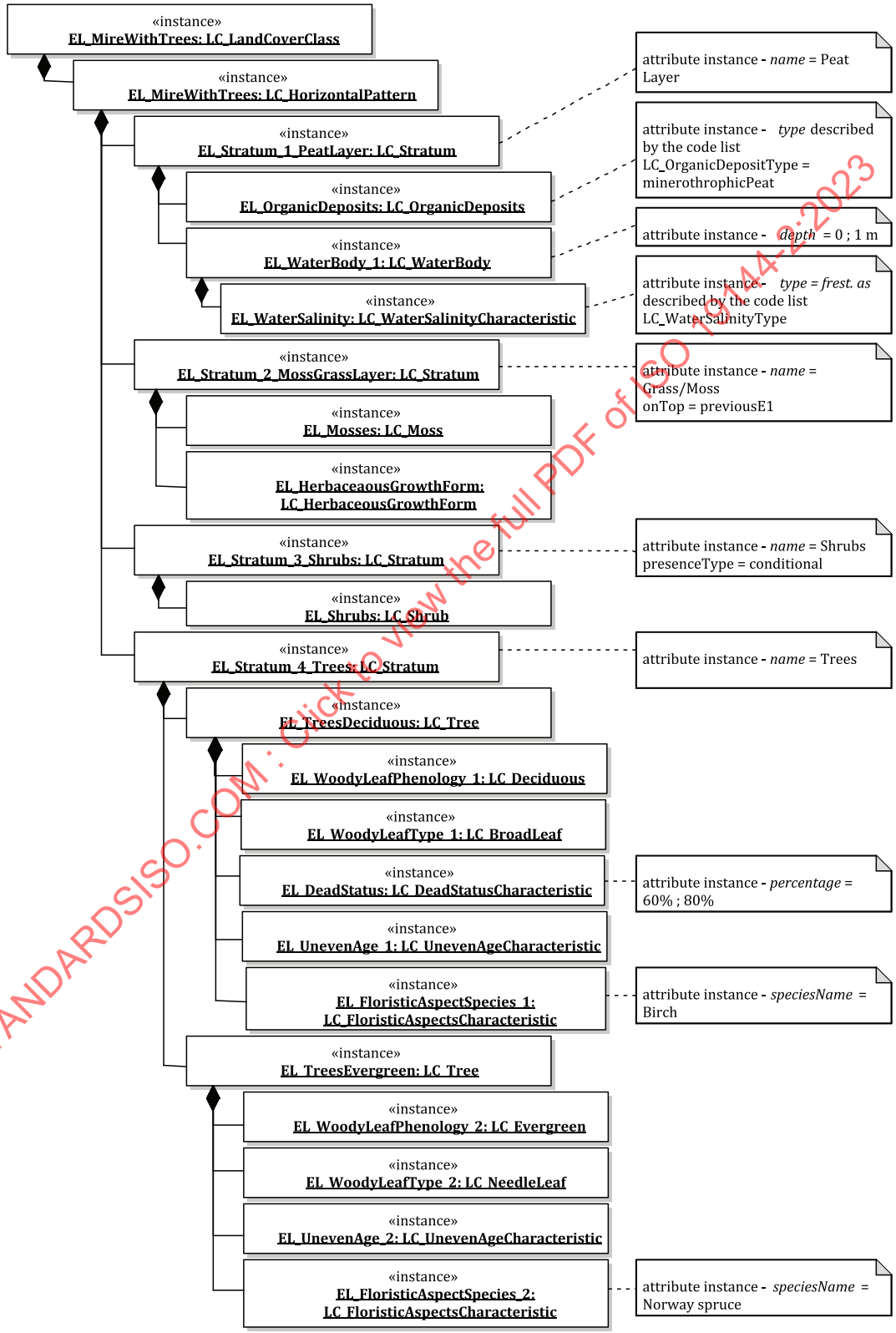


Figure C.38 — Example of peatland with trees and occasional shrubs class element composition

Annex D
(informative)

Glossary of Land Cover meta-elements

D.1 Glossary contents

This glossary contains a set of definitions that can be used with the Land Cover meta-elements described in the UML model in Clause 8. The definitions are grouped in generally the same order as the model is described. However, since some terms are used multiple times in the model, such as for attributes, the order does not match exactly. These terms are an informative part of the model and are separated into this annex to facilitate referencing and to make it clear that other definitions of terms can be used.

In order for the comparison capability of the LCML to work there has to be an agreement on terms at some level. The LCML can be used to describe a Land Cover classification system with respect to a set of definitions of terms. The model provides the structure for subdividing a Land Cover classification system class into the component metalanguage objects that can be used to define it, but a set of definitions of terms is needed to determine whether a model element (LC_Element subtype) applies. The set of terms used for the comparison can be the set defined in this glossary, or it can be another defined nationally or by an organization. However, where terms differ, a comparison using the LCML will generate different results.

EXAMPLE If there is disagreement between two glossaries on the definition of a tree, then the LCML can potentially classify the same item as a tree in one case and a shrub in another.

For a comparison between two LCML descriptions of two Land Cover classification systems to be useful, they need to be made using the same glossary of terms. Where terms differ in two glossaries, they would need to be mapped. Establishing a mapping between two glossaries is an issue of semantic interoperability that can be addressed by establishing ontologies for each glossary and creating a bridging ontological mapping. The establishment of ontologies is beyond the scope of this document. The definitions in this annex are given as one reference glossary.

In order to facilitate referencing, an alphabetical cross-reference to the items in the glossary is provided in Table D.1.

D.2 Vegetation

D.2.1 Growth forms

A growth form is a group of plants having certain morphological features in common.[26] The LCML allows the height and percentage cover of the different growth forms to be specified.

D.2.2 Height

The distance from the ground to the top of an average plant layer (stratum), expressed in metres.

D.2.3 Cover

Cover is the area of incidence of an LCML basic element over the substratum in the area of pertinence of the basic element. This is expressed as a percentage value.

D.2.4 Element portioning

Element portioning is the percent value of a single LCML basic element within an area of pertinence when two or more LCML basic elements are modelled in the same stratum.

D.2.5 Strata portioning

Strata portioning is the 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 %. This allows one to express the situation where one cannot see elements that are obscured by other elements, such as not being able to see beneath the tree canopy in views from some types of satellite imagery.

D.2.6 Growth form types

A distinction can be made between the different plant growth forms on the basis of their physiognomic aspects. Woody plants (sub-divided into Trees and Shrubs) are distinguished from Herbaceous growth forms (which are sub-divided into Forbs and Graminoids), Lichens/Mosses and Algae. Additional growth form criteria can also be used to undertake a further sub-division, for example: the quality of the main axis of shoots can be used to distinguish Woody from Herbaceous; branching symmetry to distinguish Trees from Shrubs; and physiognomy of the herbaceous plants to distinguish Forbs from Graminoids and Lichens/Mosses.[38][26]

D.2.7 Woody

Perennial plants with stem(s) and branches from which buds and shoots develop are defined as woody.[19] Semi-woody plants are included here.[17] Depending on the branching symmetry, a distinction is made between Trees and Shrubs.[38] With reference to the International Classification and Mapping of Vegetation, palms, tree ferns, etc. can also belong to this category. Depending on branching symmetry and their height, they are classified as Trees or Shrubs.

D.2.8 Trees

A tree is defined as a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown.[21]

A condition of Height is applied to separate Trees from Shrubs: woody plants higher than 5 m are classified as Trees. In contrast, woody plants lower than 5 m are classified as Shrubs. This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of a tree can be classified as Trees even if the Height is lower than 5 m. In this case, a sub-condition of physiognomic aspect is added to the Height condition.

NOTE Plants essentially herbaceous but with a woody appearance (e.g. bamboos and ferns) are classified as Trees if the height is more than 5 m and as Shrubs if the height is less than 5 m.

D.2.9 Shrubs

Shrubs are woody perennial plants with persistent woody stems and without any defined main stem, being less than 5 m tall.[21] The growth habit can be erect, spreading or prostrate.

A condition of Height is applied to separate Trees from Shrubs: woody plants higher than 5 m are classified as Trees. In contrast, woody plants lower than 5 m are classified as Shrubs. This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be

classified as Trees even if the Height is lower than 5 m. In this case, a sub-condition of physiognomic aspect is added to the Height condition.

NOTE Plants essentially herbaceous but with a woody appearance (e.g. bamboos and ferns) are classified as Trees if the height is more than 5 m and as Shrubs if the height is less than 5 m. In addition, for the element Woody (indistinct and/or intricate mixture of trees and shrubs), the higher limit is set at 7 m. This category includes: other Woody plants that are not 'shrublike' (e.g. ground lianas), Welwitschia and plants that are definitely not herbaceous (e.g. agave and cactoids).

D.2.10 Leaf phenology properties for woody growth forms

D.2.10.1 Leaf phenology

The leaf phenology is the study of leaf occurrence throughout the year in woody plants. Two types can be distinguished: Evergreen and Deciduous.

D.2.10.2 Evergreen

This term describes the phenology of perennial woody plants that are never entirely without green foliage.[21]

D.2.10.3 Deciduous

This applies to the phenology of perennial woody plants that are leafless for a certain period during the year.[21] The leaf shedding usually takes place simultaneously in connection with the unfavourable season.[40]

D.2.11 Leaf type properties for woody growth forms

D.2.11.1 Leaf type

Leaf type is applied only when characterizing Woody Growth Forms (Trees and Shrubs). A distinction is made between Broadleaf, Needleleaf and Aphyllous.

D.2.11.2 Broadleaf

This refers to trees and shrubs of the botanical group *Angiospermae*, with Gingko (*Gingko biloba*) as an exception, as it is broadleaved but taxonomically belongs to the *Gymnospermae*. Both Evergreen and Deciduous species belong to this category.

D.2.11.3 Needleleaf

This refers to trees and shrubs of the botanical group *Gymnospermae*,[21] carrying typical needle-shaped leaves. Included in this category are both evergreen conifers like pines (*Pinus* spp.), hemlock (*Tsuga* spp.) and firs (*Abies* spp.), etc., as well as deciduous conifers like larch (*Larix* spp.). Scale-like leaves, especially leaves of arbor vitae (*Thuja occidentalis*) are also included. Contrary to usual definitions, this category includes all plants with needle-like leaves, even though they are not conifers, such as some Australian acacias (e.g. *Acacia asparagoides*).

D.2.11.4 Aphyllous

This category includes plants without any leaves and plants that apparently do not have leaves in the common sense. In the first case, photosynthesis takes place through other organs, like stems, branches and twigs; in the latter case, the leaves are very short-lived or extremely reduced to scales and thorns. Characteristic genera are: *Casuarina*, *Euphorbia*, *Tamarix* and many others mostly found in arid and semi-arid regions.[26]

D.2.11.5 Broadleaf properties

The properties of broadleaf leaves can be further characterized by leaf "Arrangement" on the stem, leaf "Shape" and leaf "Venations".[22]

D.2.12 Leaf arrangement

There are four main categories of leaf arrangements on the stem.

— Alternate: one leaf attached at each node, leaves alternate direction along the stem.

— Helical (also called Rosulate): leaves form a rosette, i.e. a circular arrangement of leaves, with all the leaves at a single height. Helical elongated is with leaves at different heights (i.e. with elongated internodes).

— Opposite: two leaves attached as pairs at each node. They can be decussate: each successive pair is rotated 90° progressing along the stem; or distichous: pairs do not rotate but are in the same flat plane.

— Whorled: three or more leaves are attached at each node on the stem. As with opposite leaves, successive whorls can or can not be decussate.

D.2.13 Broad leaf shape

The following terms can be used to describe plant leaf shapes.

— Acicular (*acicularis*): slender and pointed, needle-like.

— Acuminate (*acuminata*): tapering to a long point.

— Aristate (*aristata*): ending in a stiff, bristle-like point.

— Bipinnate (*bipinnata*): each leaflet also pinnate.

— Cordate (*cordata*): heart-shaped, stem attaches to cleft.

— Cuneate (*cuneata*): triangular, stem attaches to point.

— Deltoid (*deltoidea*): triangular, stem attaches to side.

— Digitate (*digitata*): divided into finger-like lobes.

— Elliptic (*elliptica*): oval, with a short or no point.

— Falcate (*falcata*): sickle-shaped.

— Flabellate (*flabellata*): semi-circular, or fan-like.

— Hastate (*hastata*): shaped like a spear point, with flaring pointed lobes at the base.

— Lance-shaped, lanceolate (*lanceolata*): long, wider in the middle.

— Linear (*lineariz*): long and very narrow.

— Lobed (*lobata*): with several points.

— Obcordate (*obcordata*): heart-shaped, stem attaches to tapering point.

— Oblanceolate (*oblanceolata*): top wider than bottom.

— Oblong (*oblongus*): having an elongated form with slightly parallel sides.

— Obovate (*obovata*): teardrop-shaped, stem attaches to tapering point.

— Obtuse (*obtusus*): with a blunt tip.

— Orbicular (*orbicularis*): circular.

— Ovate (*ovata*): oval, egg-shaped, with a tapering point.

— Palmate (*palmata*): divided into many lobes.

— Pedate (*pedata*): palmate, with cleft lobes.

— Peltate (*peltata*): rounded, stem underneath.

— Perfoliate (*perfoliata*): stem through the leaves.

— Pinnate (*pinnata*): two rows of leaflets.

— Pinnatisect (*pinnatifida*): cut, but not to the midrib (in this case it would be pinnate).

— Reniform (*reniformis*): kidney-shaped.

— Rhomboid (*rhomboidalis*): diamond-shaped.

— Round (*rotundifolia*): circular.

— Sagittate (*sagittata*): arrowhead-shaped.

— Spatulate, spathulate (*spathulata*): spoon-shaped.

— Spear-shaped (*hastata*): pointed, with barbs.

— Subulate (*subulata*): awl-shaped with a tapering point.

— Sword-shaped (*ensiformis*): long, thin, pointed.

— Trifoliate, ternate (*trifoliata*): divided into three leaflets.

— Tripinnate (*tripinnata*): pinnately compound in which each leaflet is itself bipinnate.

— Truncate (*truncata*): with a squared off end.

— Unifoliate (*unifoliata*): with a single leaf.

D.2.14 Broadleaf venation

Leaf venation is the arrangement of the veins on the leaf. The following terms can be used to describe leaf venation.

— Dichotomous: there are no dominant bundles, with the veins forking regularly by pairs. An example is the Ginkgo and some pteridophytes species.

— Pinnate reticulate: the veins arise pinnately from a single mid-vein and subdivide into veinlets. These, in turn, form a complicated network. This type of venation is typical for (but by no means limited to) dicotyledons.

— Palmate reticulate: palmate-netted, palmate-veined, fan-veined; several main veins diverge from near the leaf base where the petiole attaches, and radiate toward the edge of the leaf; e.g. most *Acer* (maples).

— Parallel (expanded leaf): three main veins branch at the base of the lamina and run essentially parallel subsequently, as in *Ceanothus.* A similar pattern (with 3-7 veins) is especially conspicuous in *Melastomataceae*.