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Geographic information — Classification systems —

Part 2: Land Cover Meta Language (LCML)

Information géographique — Systèmes de classification —

Partie 2: Métalangage de couverture du sol (LCML)

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 19144-2 was prepared jointly by the Food and Agriculture Organization of the United Nations (UNFAO) and Technical Committee ISO/TC 211, *Geographic information/Geomatics* under a cooperative agreement between the two organizations.

ISO 19144 consists of the following parts, under the general title *Geographic information — Classification systems*:

— *Part 1: Classification system structure*

— *Part 2: Land Cover Meta Language (LCML)*

Introduction

Efficient assessment of land cover and the ability to monitor change are fundamental to sustainable management of natural resources, environmental protection, food security and successful humanitarian programmes. Such information is also required to help towards raising levels of nutrition, improving agricultural productivity, enhancing the lives of rural populations and contributing to sustainable growth of the world economy. However, in the past, policy-makers and planners have not had access to reliable and comparable land cover data, not only for lower-income countries but 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 not been possible to compare or to exchange information between current systems.

The aim of this part of ISO 19144 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 a common, umbrella land cover classification system structure. 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 part of ISO 19144 provides a metalanguage expressed as a UML model that allows different land cover classification systems to be described.

This part of ISO 19144 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.

Geographic information — Classification systems —

Part 2: Land Cover Meta Language (LCML)

1 Scope

This part of ISO 19144 specifies a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different land cover classification systems to be described based on the physiognomic aspects. This part of ISO 19144 also specifies the detailed structure of a register for the extension of LCML but does not specify the maintenance of the register. This part of ISO 19144 recognizes that there exist a number of land cover classification systems. 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 Conformance

2.1 Classes

Three conformance classes are identified in this part of ISO 19144.

2.2 Conformance of a land cover classification system

A land cover classification system, as defined in accordance with the LCML defined in this part of ISO 19144, shall satisfy the conditions specified in the following abstract test suite:

a) ISO 19144-1 (Annex A) for general conformance of the classification system;

b) A.2.

2.3 Conformance of a register for the extension of the metalanguage

The register defined in this part of ISO 19144 shall satisfy all of the conditions specified in the following abstract test suites:

a) ISO 19135 for the general register structure;

b) A.3.1 for the minimum register content;

c) A.3.2 for uniqueness of registered metaclass names;

d) A.3.3 for backward compatibility.

2.4 Conformance of a comparison process of land cover classification systems

The process of comparison of two land cover classification systems shall be done by developing descriptions of the two land cover classification systems, each in accordance with the abstract test suite in A.2, and then identifying the differences in accordance with the abstract test suite in A.4.

3 Normative references

The following referenced documents are indispensable for the application 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 19109:2005, *Geographic information — Rules for application schema*

ISO/TS 19103:2005, *Geographic information — Conceptual schema language*

ISO 19144-1:2009 *Geographic information — Classification systems — Part 1: Classification system structure*

ISO 19135:2005, *Geographic information — Procedures for item registration*

4 Terms, definitions, and abbreviations

4.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The technical terms applying to plant physiognomy, and terms from other disciplines used to establish the classifiers in the classification scheme are not defined in this part of ISO 19144.

4.1.1
abstract test suite
abstract test module specifying all the requirements to be satisfied for conformance

[ISO 19105:2000, 3.4]

4.1.2
classification
abstract representation of real world phenomena using **classifiers** (4.1.4)

[ISO 19144-1:2009, 4.1.4]

4.1.3
classification system
system for assigning objects to classes

[ISO 19144-1:2009, 4.1.5]

4.1.4
classifier
definition used to assign objects to **legend classes** (4.1.11)

[ISO 19144-1:2009, 4.1.6]

NOTE Classifiers can be algorithmically defined, or defined according to a set of **classification system** (4.1.3) specific rules.

4.1.5
feature
abstraction of real world phenomena

[ISO 19101:2002, 4.11]

EXAMPLE The phenomenon named “Eiffel Tower” can be classified with other similar phenomena into a feature type named “tower”.

4.1.6
item class
set of items with common properties

[ISO 19135:2005, 4.1.6]

NOTE Class is used in this context to refer to a set of instances, not the concept abstracted from that set of instances.

4.1.7
land cover
observed (bio)physical cover on the Earth's surface

[UNFAO LCCS 2:2005]

NOTE Land cover is distinct from **land use** (4.1.9).

4.1.8
land cover metalanguage
logical general model used to describe **land cover** (4.1.7) **features** (4.1.5) from which more specific rules can be described to create a particular **classification system** (4.1.3)

4.1.9
land use
arrangements, activities and inputs people undertake in a certain **land cover** (4.1.7) type to maintain it or produce change

[UNFAO LCCS 2:2005]

NOTE 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.

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.

4.1.10
legend
application of a **classification** (4.1.2) in a specific area using a defined mapping scale and specific data set

[UNFAO LCCS 2:2005]

4.1.11
legend class
class resultant from the application of a **classification** (4.1.2) process

[ISO 19144-1:2009, 4.1.16]

NOTE In order to avoid confusion with respect to the term "class", the result of a classification process will be termed a "legend class". This use of the term "class" is distinct from the term "class" as used in UML modelling.

4.1.12
physiognomy
general appearance of an object or terrain, without reference to its underlying or scientific characteristics

4.1.13
register
set of files containing identifiers assigned to items with descriptions of the associated items

[ISO 19135:2005, 4.1.9]

4.1.14
registry
information system on which a **register** (4.1.13) is maintained

[ISO 19135:2005, 4.1.13]

4.2 Abbreviations

CEC Commission of the European Communities

CORINE	Coordination of Information on the Environment, EU
LCCS	Land Cover Classification System
LCML	Land Cover Meta Language
LC	Prefix used to identify classes in the Land Cover Meta Language
TDS	Total Dissolved Solids
UML	Unified Modelling Language
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFAO	United Nations Food and Agriculture Organization
UNFAO LCCS	UNFAO Land Cover Classification System

5 Notation

The conceptual schema specified in this part of ISO 19144 is described using the Unified Modelling Language (UML), following the guidance of ISO/TS 19103.

Several model elements used in this schema are defined in other ISO geographic information standards. By convention within ISO/TC 211, names of UML classes, with the exception of basic data type classes, include a two letter prefix that identifies the standard and the UML package in which the class is defined. UML classes defined in this part of ISO 19144 have the two letter prefix of LC. Examples in this part of ISO 19144 have the two letter prefix EL. The classes in the meta model in Annex B use the prefix LM. Table 1 lists the other standards and packages in which UML classes used in this part of ISO 19144 have been defined.

Table 1 — Sources of externally defined UML classes

Prefix	Standard	Package
CL	19144-1	Classification System Structure
RE	19135	Procedures for registration

In accordance with the ISO/IEC Directives, Part 2, the decimal sign used in the body of the text in this part of ISO 19144 is a comma. However, in the UML models in figures, and in strings of Object Constraint Language text taken from the model as quoted in curly brackets ” {} “, the decimal sign used is a period.

6 Context

The purpose of this part of ISO 19144 is to define a common reference structure for the comparison and integration of data for any generic land cover classification system. The approach has been to define a Land Cover Meta Language (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 part of ISO 19144 defines a LCML for a land cover classification system[1)]. It recognizes that there exist a number of land cover classification systems and nomenclatures 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

1) The LCML is derived from the concepts in the land cover classification system (UNFAO LCCS version 3) established by the Food and Agricultural Organization (FAO) of the United Nations [34], [35]. The UNFAO 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.

set in law in some nations with respect to land use legislation. For example, 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.

The approach taken in this part of ISO 19144 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 part of ISO 19144 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 to produce global regional and national data sets able to be reconciled at different scales and detail level and geographic places.

One example of a land cover classification system is the UNFAO Land Cover Classification System.[34] The purpose of the UNFAO LCCS, which is standardized by the UNFAO, is to give to the international community one possible system to classify land cover with a parametric approach that is compliant with the metamodel defined in this part of ISO 19144. Other land cover classification systems can also be defined by other regional or national bodies. The UNFAO LCCS is 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 complies with 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 comply with ISO 19144-1. The structure used to represent the classified data can be that of a discrete coverage as described in ISO 19123. The classifiers described in accordance with the LCML can be maintained in a register, compliant with ISO 19135 and with ISO 19144-1; that is, the classes described using the metalanguage defined in this part of ISO 19144 can populate a register for classifiers as described in ISO 19144-1. Registration within this part of ISO 19144 is used in a very different way. It is used to allow for extension of the LCML.

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 in two categories: “basic metalanguage-elements”, the elements that constitute the main physiognomic aspects of biotic and abiotic cover features, e.g. for biotic features trees, shrubs, herbaceous vegetation, and “metalanguage-element properties” that further define the physiognomic/structural aspect of the basic objects.

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 meta-elements. The definition of these characteristics in this part of ISO 19144 is informative, not normative, i.e. other sets of characteristics can be established and used with the LCML basic 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 to deal with the all functional elements of the language (basic metalanguage-elements and properties) and the different strata.

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 scheme 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 comply 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 are in compliance with 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 part of ISO 19144 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 may use as a geographical reference (e.g. for land use, climatic or ecological studies).

7.2 LCML approach to class definition

7.2.1 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 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.

7.2.2 Land cover classification system design criteria

Land cover classes shall be defined by a set of land cover metalanguage-elements as represented by the class LC_Element and its subtypes. Further definition of the land cover classes may 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 Cover and Height and arrange them in strata. At any level specific characteristics can be added.

The non-vegetated metaclasses have a specular approach.

The basic elements of each of the two 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 these elements (or part of them) can be arranged in one or more layers or strata.

Further definition of the land cover classes may 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.

7.2.3 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 7.2.4 to 7.2.6.

7.2.4 Land cover metalanguage-elements

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 may be combined to form strata and how these may be combined to form land cover metaclasses.

7.2.5 Layering

Several vegetated or non-vegetated basic metalanguage-elements may be combined to form a layer or stratum and these strata may 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.

7.2.6 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 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_ValueTypes define the allowable basic numerical types with constraints. The LC_Registers package includes the definition of the registers which may be used to extend the LCML. This is represented in Figure 1.

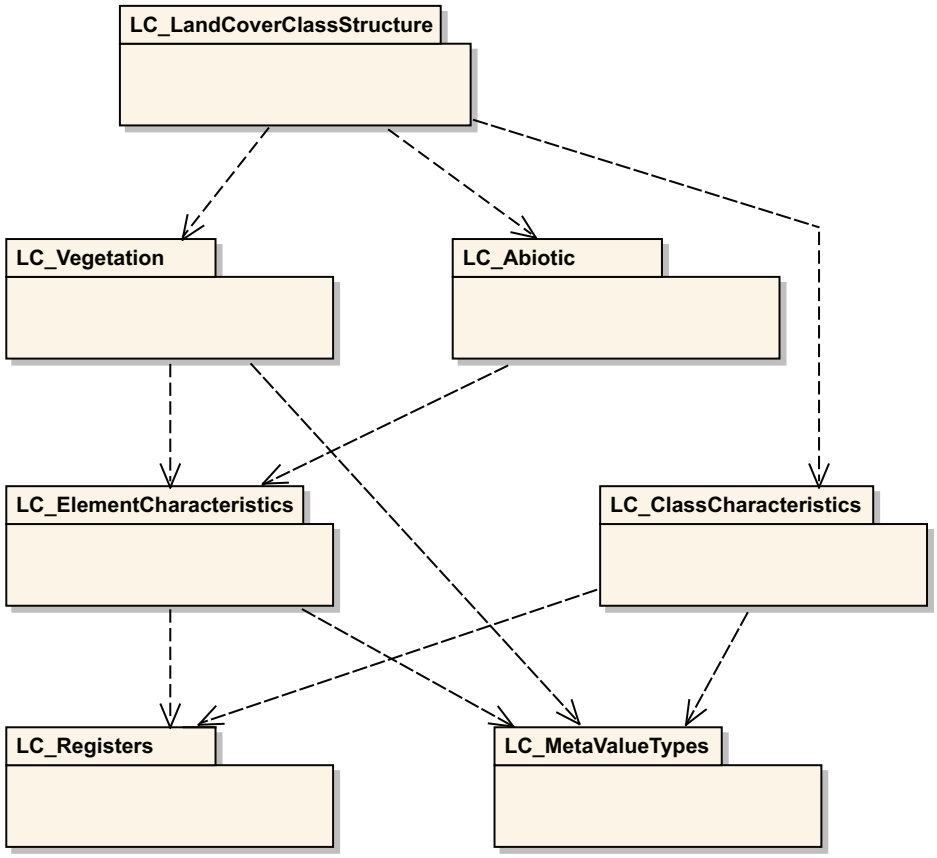


Figure 1 — LCML packages

8 LCML objects

8.1 Introduction to LCML objects

The LCML is a metalanguage which may be used to describe a wide variety of land cover classification systems. The LCML operates by describing each 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 class in a land cover classification system may 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 class from one system is composed of, for example LC_Element subtype A+B+Q+Y and another of LC_Element subtype A+B+Y then one can determine 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 part of ISO 19144 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 do 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 Classification system structure

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[2)] that are established to exhaustively represent a particular aspect of the reality. The totality or a subset of these classes may be selected to describe a particular geographic area establishing a legend or nomenclature. A land cover classification system is general in that its classification scheme 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. The metalanguage provides the structure so that a classification system may be described.

The initial (root) class of the LCML 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_LandCoverDescriptor. The LC_LandCoverDescriptor object describes the LC_LandCoverClass, which is a subtype of CL_LegendClass as defined in ISO 19144-1. The LC_LandCoverDescriptor 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 part of ISO 19144 and established in conformance with ISO 19109 shall include 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 may 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 may also be organized so as to describe a horizontal pattern through the 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 subelements 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 may be defined as required. Registration is described in Clause 9.

2) The term *class* has several meanings in this part of ISO 19144. The UML modelling language uses the term *class* 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 also used in this part of ISO 19144 to represent a construct in a classification scheme. A classification scheme 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 scheme metalanguage such as the LCML. 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. Adjectives have been used in this document where possible to reduce this confusion, for example UML classes can be called “UML classes” and classification scheme 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.

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[3)] in conformance with ISO/TS 19103. The schema of the LCML register is described in 9.3.2.

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_LandCoverDescriptor objects. The LC_LandCoverClassificationSystemMetaLanguage object is a description of a land cover classification system as represented by the class LC_LandCoverClassificationSystem. The individual LC_ LandCoverDescriptor objects may 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.

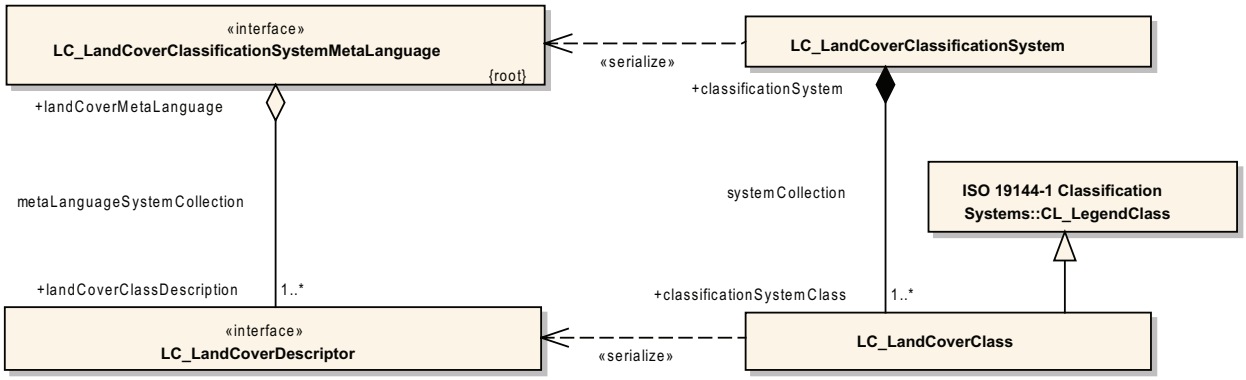


Figure 2 — High level structure of the Land Cover Classification Model

8.5.2 High level structure classes

8.5.2.1 LC_LandCoverClassificationSystemMetaLanguage

The initial (root) class of the LCML is the LC_LandCoverClassificationSystemMetaLanguage object. This 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_LandCoverDescriptor.

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 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.

3) The UML model makes use of constructs available in UML 2.0. In particular the elements of the metalanguage are described as interfaces. The Land Cover Classification System elements conform to the interface that the Land Cover Meta Language model element establishes.

8.5.2.2 LC_LandCoverClassificationSystem

The LC_LandCoverClassificationSystem metalanguage 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_LandCoverDescriptor

The LC_LandCoverDescriptor object is the metalanguage level template for a land cover class in a land cover classification system. The LC_LandCover object is used to describe the LC_LandCoverClass.

This 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_LandCoverDescriptor.

8.5.2.4 LC_LandCoverClass

The LC_LandCoverClass metalanguage object is the result of the serialization of the LC_LandCover object; that is, it is related to LC_LandCoverDescriptor by a dependency relationship that indicates that the LC_LandCoverClass is described by the serialization of the metalanguage objects that compose the LC_LandCoverDescriptor. 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 class CL_LegendClass as defined in ISO 19144-1; that is, it is a specialization of a general classification system Legend Class 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_LandCover, that when realized produces a class in a land cover classification system. Occurrences of LC_Element may be combined in layers using the *stratumComposition* relationship between LC_Element and LC_Stratum. The relationship of the LC_Elements within a layer is given by the *inSameStrataRelationship*. Several types of relationships including a *sequentialTemporalRelationship*, a *conditional* relationship and an *exclusive* (XOR) relationship may be described by the LC_ElementRelationInSameStratum association class. There may 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 may be described. Elements in a stratum may be built upon the same baseline or they may be indicated to be on top of another stratum. This is represented in Figure 3.

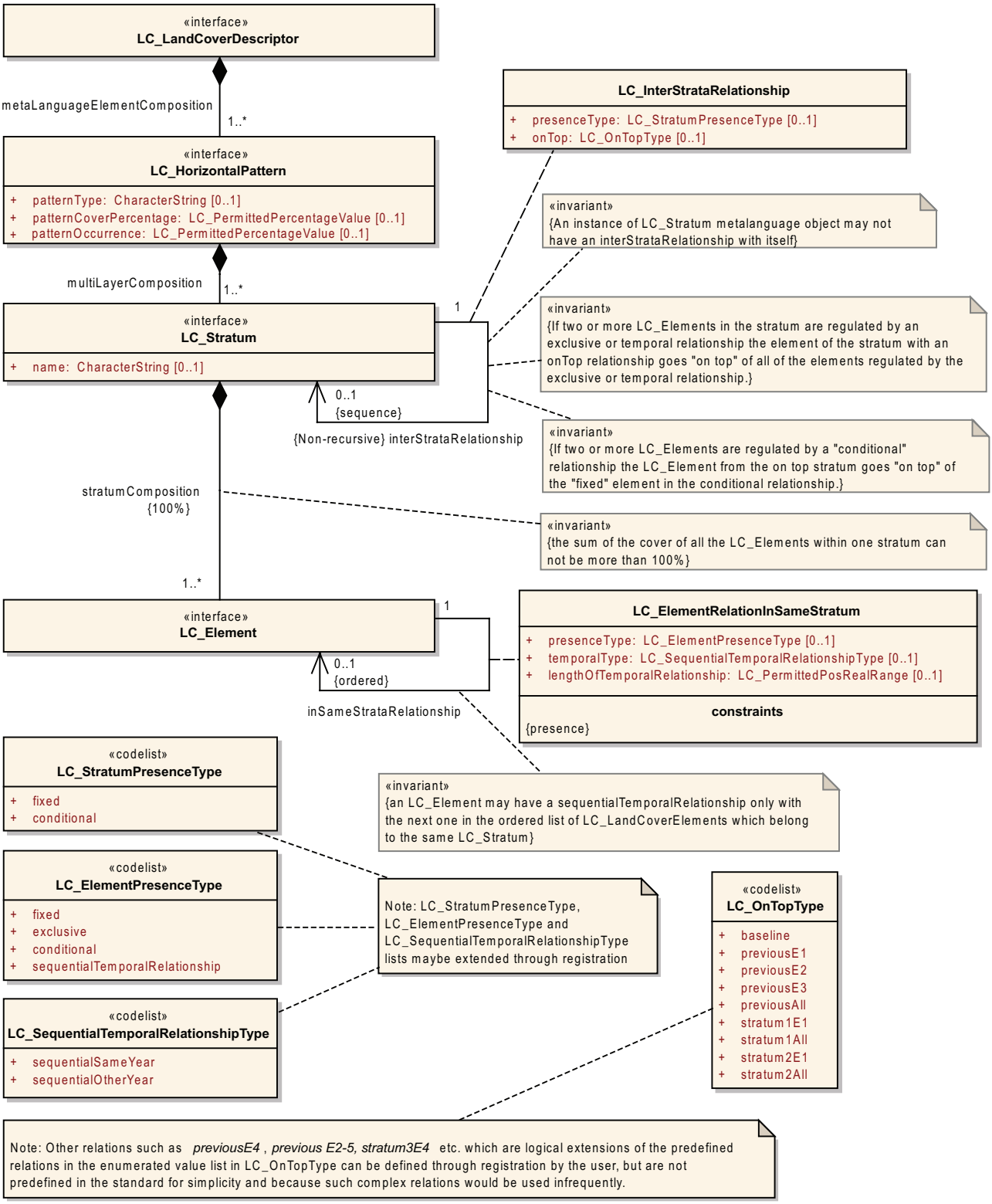


Figure 3 — Land Cover Meta Language object structure

8.6.2 Land Cover Meta Language object structure classes

8.6.2.1 LC_LandCoverDescriptor

The Land Cover Meta Language object structure establishes the rules for the aggregation of occurrences of LC_Element, into the object LC_LandCoverDescriptor, that when serialized describe a class in a land cover classification system. The LC_LandCoverDescriptor objects are composed of classification system elements LC_Element. These elements may 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 may also be organized so as to describe a horizontal pattern through LC_HorizontalPattern.

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

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). A horizontal pattern may be used for a complex Land Cover object composed by two or more distinct land cover features that will be handled as a "unicum"[4] independently from scale constraints. An example is 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.

NOTE A horizontal pattern for an object is distinct from the combination of two LC_LandCoverDescriptor objects that would otherwise be distinct but are combined because they cannot be distinguished at a given scale. For example, closed trees (class A) in a grassland (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 meta classes.

The object LC_HorizontalPattern has three optional attributes: *patternType*, *patternCoveragePercentage* and *patternOccurrence*. The permitted values of the attribute *patternType* are described in free text in a character string. The permitted values of the attribute *patternCoveragePercentage* are described by the value object LC_PermittedPercentageValue. The permitted values of the attribute *patternOccurrence* are described by the value object LC_PermittedPercentageValue.

8.6.2.3 LC_Stratum

Individual or groups of land cover elements (vegetated and/or non-vegetated) may 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_LandCoverDescriptor object. Several strata may be combined in an ordered sequence to model specific land cover classes in certain environments. 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 may 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 may be a component of the description of a land cover class in a land cover classification system, and 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.

4) The term "unicum" in this context designates a heterogeneous set of land cover elements represented as a single unit. "A unique example, specimen, or thing". See Shorter Oxford English Dictionary (SOED) 1993.

— It has a composition relationship *stratumComposition* 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 the optional attribute *name* which may be used to describe the horizontal pattern. The permitted value of the attribute name is in free text in a character string.

8.6.2.4 LC_InterStrataRelationship

The association class LC_InterStrataRelationship defines the relationship between instances of the LC_Stratum object.

A constraint is that {An instance of LC_Stratum metalanguage object may not have an interStrataRelationship with itself}.

The association class LC_InterStrataRelationship has two attributes: *presenceType* and *onTop*. The permitted values of the attribute *presenceType* are described by the code list LC_StratumPresenceType. The permitted values of the attribute *onTop* are defined by the code list LC_OnTopType.

The attribute *presenceType* allows one to indicate whether a stratum is fixed (mandatory); that is, it is always present in the composition of elements for an LC_LandCoverDescriptor metalanguage object, or whether it is conditional. This allows one to model a situation where a certain stratum is permitted but not always present in the definition of an LC_LandCoverDescriptor 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 *presenceType* of conditional is useful when describing a land cover classification system that contains classes or legends based on ambiguous definitions or when one wants to indicate that a further refinement of the land cover class is possible. The default value of the attribute *presenceType* is “fixed”.

The *onTop* attribute indicates a relationship between strata where one stratum is defined in reference to another. For example three elements: trees, shrubs and herbs might 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_LandCoverDescriptor metalanguage object have a common background reference. That is, the default relationship is to the common baseline. It is necessary to define other values of the *onTop* relationship explicitly. An example, 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 the element of the stratum with an *onTop* relationship 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.}.

8.6.2.5 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.

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

This object has two relationships:

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

— There is an *inSameStrataRelationship* between separate instances of the LC_LandCoverElement objects. The elements in the same strata 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 association class LC_ElementRelationInSameStratum.

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

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

8.6.2.6 LC_ElementRelationInSameStratum

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

The association class LC_ElementRelationInSameStratum has three attributes: *presenceType*, *temporalType* and *lengthOfTemporalRelationship*. The permitted values of the attribute *presenceType* are described by LC_ElementPresenceType. The permitted values of the attribute *temporalType* are described by the value object LC_SequentialTemporalRelationshipType. The permitted values of the attribute *lengthOfTemporalRelationship* are defined by the value object LC_PermittedPosRealRange.

The attribute *presenceType* allows one to indicate whether an LC_Element in a stratum is fixed (mandatory); that is, it is always present in the composition of elements for an LC_Stratum and indirectly for a LC_LandCoverDescriptor metalanguage object, or whether it is exclusive, conditional (optional) or whether a sequential temporal relationship exists. This allows one to model a situation where a certain LC_Element is permitted but not always present in the definition of an LC_Stratum and indirectly an LC_LandCoverDescriptor metalanguage object; that is it is optional, and also the situation where one of two LC_Elements is permitted but not both (exclusive OR - XOR).

The attribute *temporalType* for the association class LC_ElementRelationInSameStratum is optional and by default that there is no sequential temporal relation. This attribute allows one to indicate a temporal relationship between LC_Elements. One element may exist at one time and another element at a different time.

The attribute *lengthOfTemporalRelationship* in the 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 8.6.2.6. See 8.28.2.6 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 when one wants to indicate that a further refinement of the land cover class is possible.

8.6.2.7 LC_StratumPresenceType

The code list LC_StratumPresenceType contains a list of types of stratum relationships, see 8.6.2.4. This list contains two types: fixed and conditional. This list may be extended through registration. The attribute *presenceType* for the 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_LandCoverDescriptor metalanguage object.

— *conditional* – The LC_Stratum may exist in the LC_HorizontalPattern and indirectly in the LC_LandCoverDescriptor metalanguage object, dependent upon the existence of another LC_Stratum.

8.6.2.8 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 *sequentialTemporalRelationship*. This list may be extended through registration. The attribute presenceType for the 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 strata

— *exclusive* – One of two LC_Elements may exist in the stratum (XOR relationship)

— *conditional* (optional) – The existence of an LC_Element in a strata may exist dependant upon the existence of another LC_Element

— *sequentialTemporalRelationship – Two LC_Elements may exist in a strata linked with a sequential* temporal relationship.

8.6.2.9 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 may be extended through registration.

8.6.2.10 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 8.6.2.4. The onTop relationship make use of a code list in order to make it possible to define as many values as one wants and give them explicit meanings. This is the most flexible approach to handling the onTop relation. This list contains nine types. This list may be extended through registration. The attribute *onTopType* for the 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_LandCoverDescriptor 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 may 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_LandCoverDescriptor 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_LandCoverDescriptor 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_LandCoverDescriptor 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_LandCoverDescriptor 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, but are not predefined in this part of ISO 19144 for 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. This is represented in Figure 4.

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 may 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. For example, a particular concept may have a detailed explicit class in one land cover classification system but it may only be able to represent it by a more general 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 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 may be used in any land cover classification system. They are a set of reference definitions for the LCML.

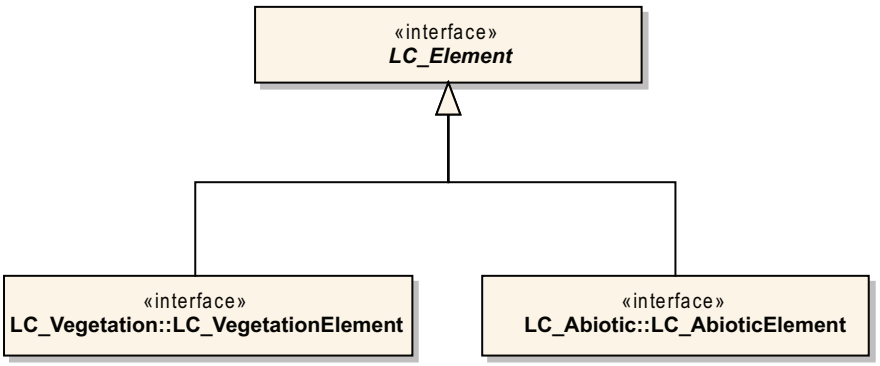


Figure 4 — Subtypes of LC_LandCoverElement

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 may 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 may 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 5.

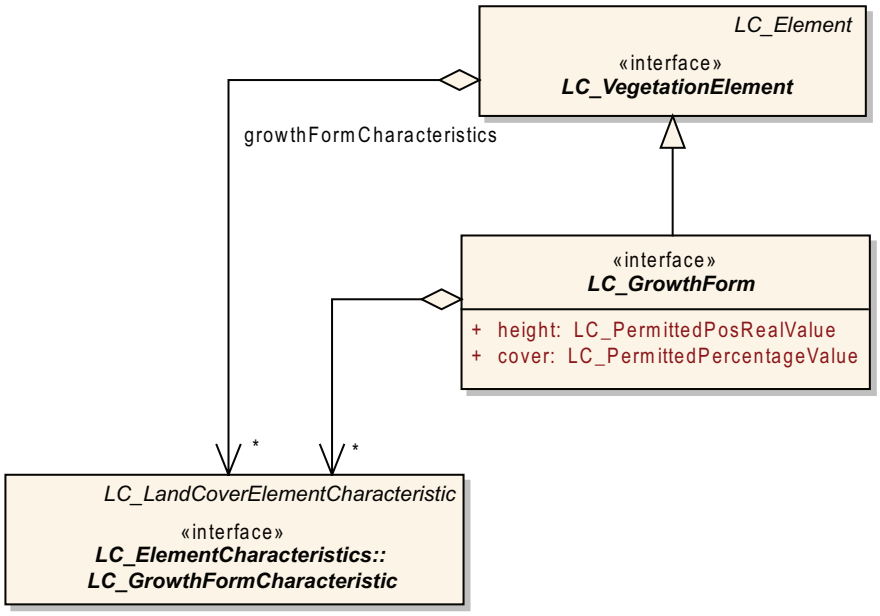


Figure 5 — Subtypes of LC_VegetationElement

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 *cover*. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealValue. The permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageValue. 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.

8.8.2.2 LC_GrowthFormCharacteristic

The component LC_GrowthFormCharacteristic is related to the LC_VegetationElement metalanguage object by the relation *growthFormCharacteristics*. The component LC_GrowthFormCharacteristic may 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 6.

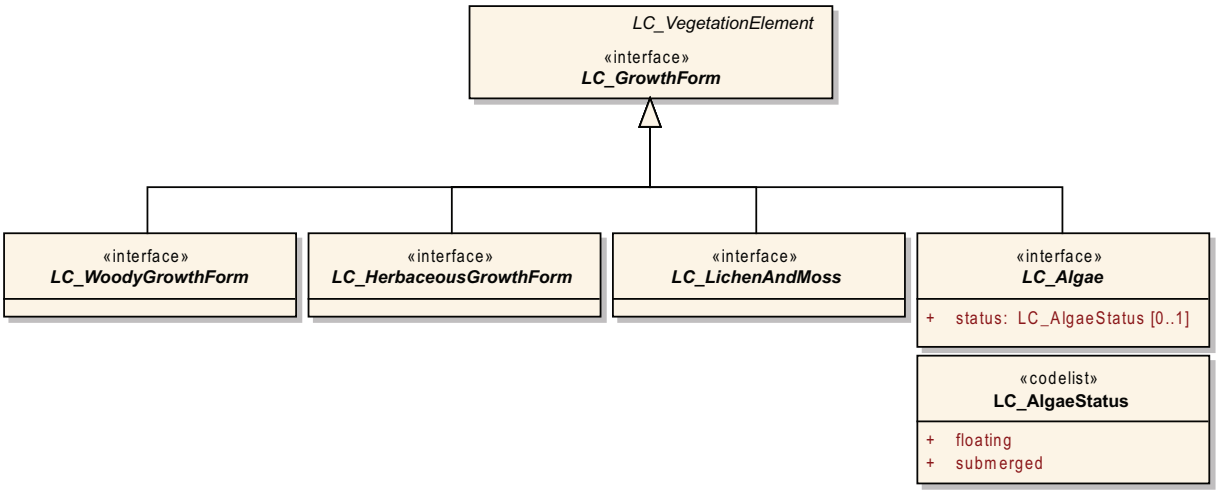


Figure 6 — Subtypes of LC_GrowthForm

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* and *submerged*. This list may 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.

LC_WoodyGrowthLeafType is an association class on the component relationship between the class LC_WoodyLeafType and LC_WoodyGrowthForm. LC_WoodyGrowthLeafPhenology is an association class on the component relationship between the class LC_WoodyLeafPhenology and LC_WoodyGrowthForm.

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 7.

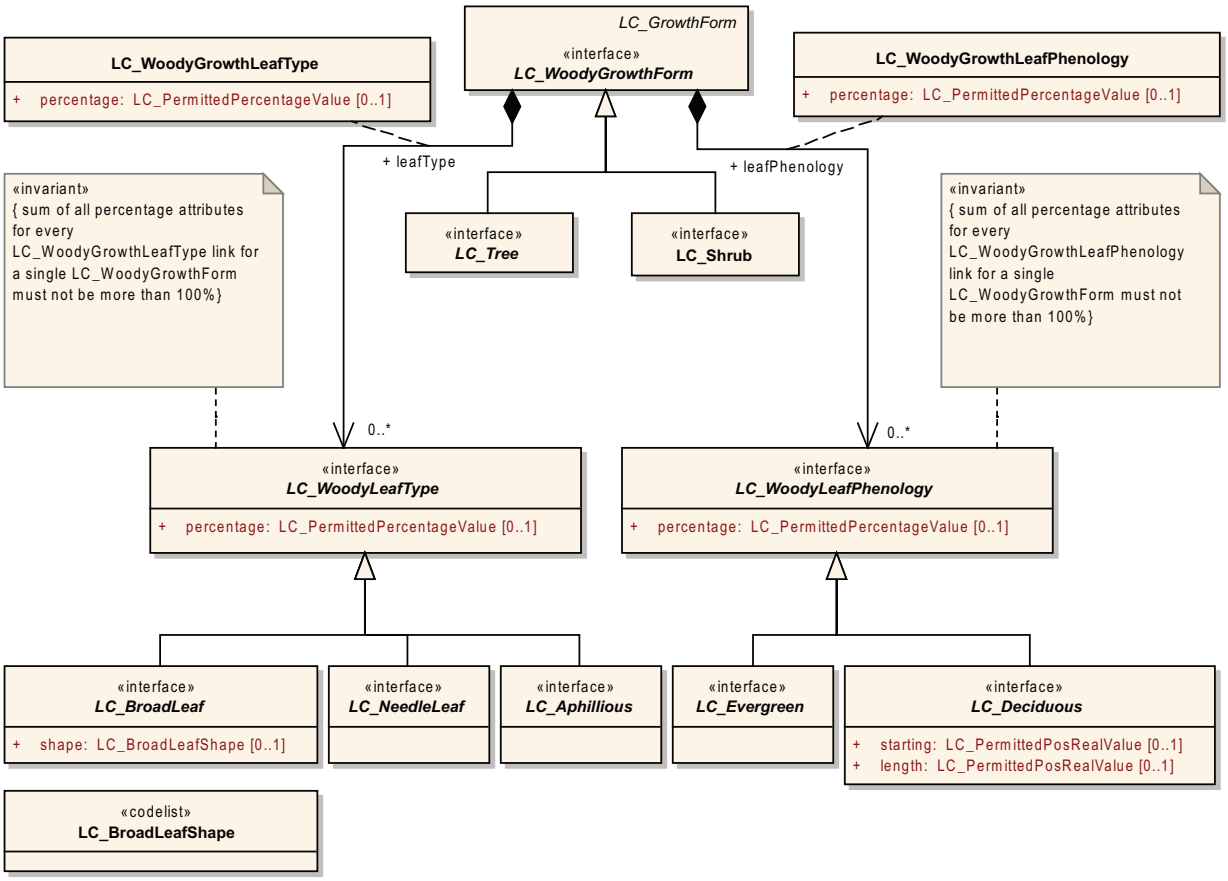


Figure 7 — Subtypes of LC_WoodyGrowthForm

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 (informative).

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 (informative).

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_Aphillious and LC_BroadLeaf. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageValue with the constraint that the {it is required that the sum of all percentage attributes for every LC_WoodyGrowthLeafType link for a single LC_WoodyGrowthForm not be more than 100 %}. The component LC_WoodyLeafType may 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. It has one optional attribute: *shape*. The permitted values of the attribute *shape* are described by the enumerated value object LC_BroadLeafShape. This sub-component may 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 may be established through registration. This sub-component may 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_Aphillious

The LC_Aphillious metalanguage object is a subtype of LC_WoodyLeafType. Attributes may be established through registration. This sub-component may 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_WoodyGrowthLeafType

LC_WoodyGrowthLeafType is an association class on the component relationship *leafType* between the class LC_WoodyLeafType and LC_WoodyGrowthForm. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageValue.

8.10.2.8 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_PermittedPercentageValue with the constraint that the {it is required that the sum of all percentage attributes for every LC_WoodyGrowthLeafPhenology link for a single LC_WoodyGrowthForm not be more than 100 %}. The component LC_WoodyLeafPhenology may 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_Evergreen

The LC_Evergreen metalanguage object is a subtype of LC_WoodyLeafPhenology. Attributes may be established through registration. This sub-component may 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.

8.10.2.10 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_PermittedPosRealValue. This sub-component may 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.

8.10.2.11 LC_WoodyGrowthLeafPhenology

LC_WoodyGrowthLeafPhenology is an association class on the component relationship leafPhenology between the class LC_WoodyLeafPhenology and LC_WoodyGrowthForm. It has one optional attribute: *percentage*. The permitted values of the attribute *percentage* are described by the value object LC_PermittedPercentageValue.

8.10.2.12 LC_BroadLeafShape Type

The code list LC_BroadLeafShape contains a list of broadleaf arrangements. At the metalanguage level this list is empty, but it may be populated through registration.

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_Gramineae 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 a herbaceous growth form. This is represented in Figure 8.

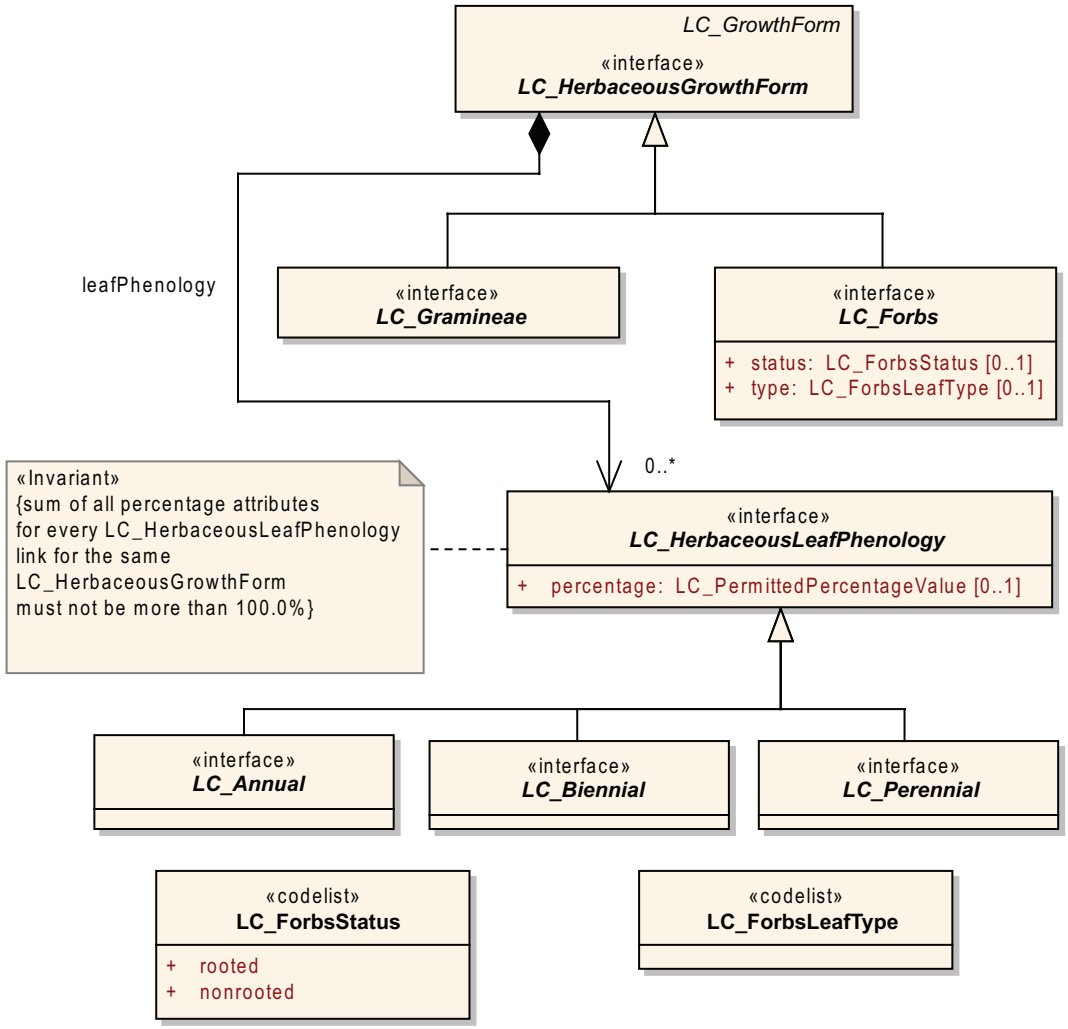


Figure 8 — Subtypes of LC_HerbaeceousGrowthForm

8.11.2 LC_HerbaceousGrowthForm classes

8.11.2.1 LC_Gramineae

The LC_Gramineae 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 gramineae 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 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_WoodyGrowthForm 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_ PermittedPercentageValue with the constraint that the {it is required that the sum of all percentage attributes

for every LC_HerbaceousLeafPhenology link for the same LC_HerbaceousGrowthForm not be more than 100.0 %}. The component LC_HerbaceousLeafPhenology may 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_Annual

The LC_Annual metalanguage object is a subcomponent of LC_HerbaceousLeafPhenology. Attributes may be established through registration. This sub-component may 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_Biennial

The LC_Biennial metalanguage object is a subcomponent of LC_HerbaceousLeafPhenology. Attributes may be established through registration. This sub-component may 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.

8.11.2.6 LC_Perennial

The LC_Perennial metalanguage object is a subcomponent of LC_HerbaceousLeafPhenology. Attributes may be established through registration. This sub-component may 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_ForbsLeafStatus

The code list LC_ForbsLeafStatus contains a list of leaf types. This list contains two types: *terrestrial* and *floating*. This list may be extended through registration.

8.11.2.8 LC_ForbsLeafType

The code list LC_ForbsLeafType contains a list of leaf types. At the metalanguage level this list is empty, but it may be populated 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 9.

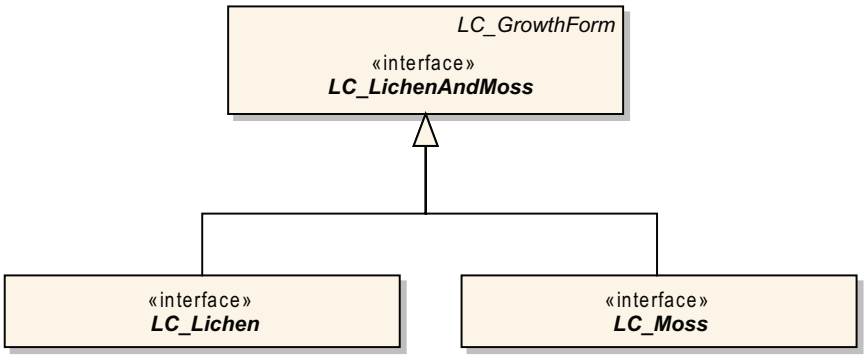


Figure 9 — Subtypes of LC_LichenAndMoss

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 10.

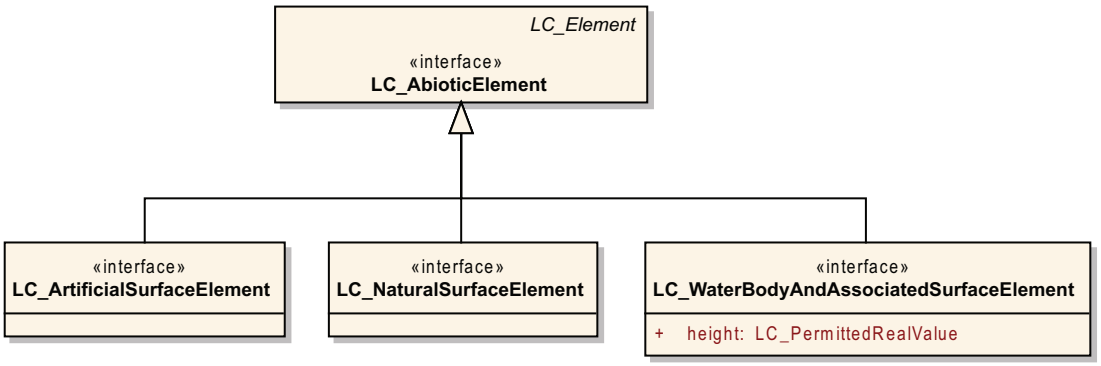


Figure 10 — Subtypes of LC_AbioticElement

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. There is one attribute: *height*. The permitted values of *height* are defined by the value object LC_PermittedRealValue. 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 and a relationship with the component LC_ArtificialSurfaceCharacteristic. This is represented in Figure 11.

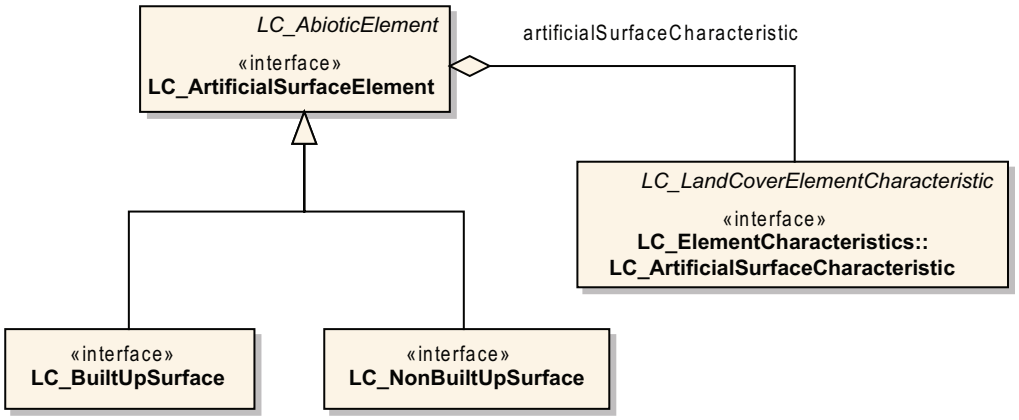


Figure 11 — Subtypes of LC_ArtificialSurfaceElement

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 may 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 12.

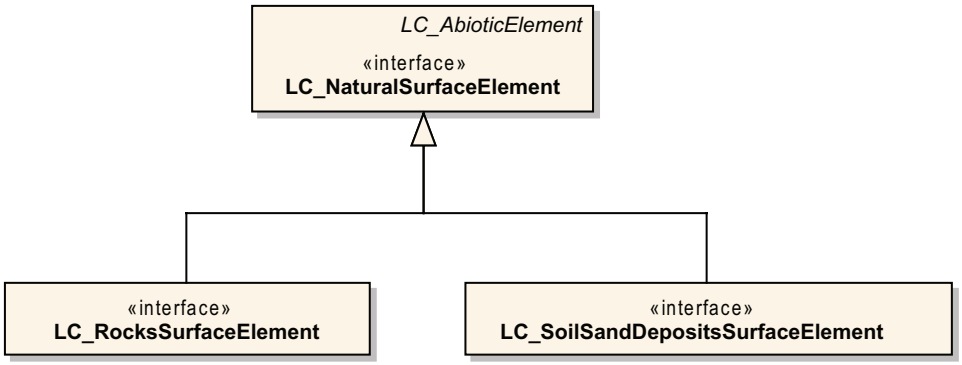


Figure 12 — Subtypes of LC_NaturalSurfaceElement

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.

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 four subtypes: LC_WaterBody, LC_Snow, LC_Ice and LC_Permafrost and a relationship to two components LC_WaterAndAssociatedSurfaceCharacteristic and LC_PeriodicVariation. This is represented in Figure 13.

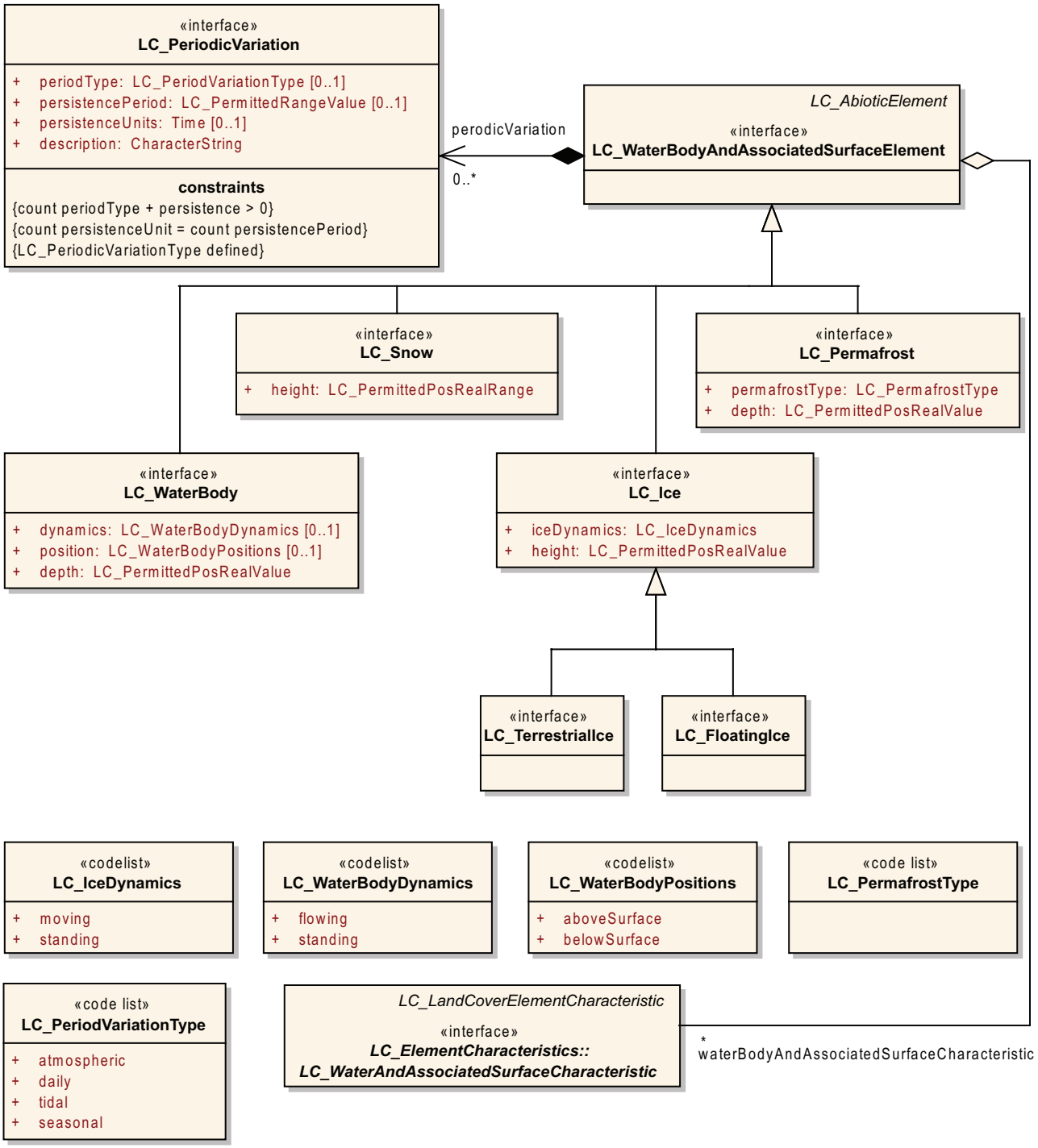


Figure 13 — Subtypes of LC_WaterBodyAndAssociatedSurfaces

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 one attribute: *depth* and two optional attributes: *dynamics* and *position*. The permitted values of the attribute *depth* are described by the value object LC_PermittedPosRealValue. Note that depth is negative to height. The permitted values of the optional attribute *dynamics* are described by the enumerated value object LC_WaterBodyDynamics. The permitted values of the optional attribute *position* are described by the enumerated value object LC_WaterBodyPositions. Other attributes may 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 one attribute: height. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealValue Other attributes may 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: *iceDynamics* and *height*. The permitted value of the attribute *dynamics* is described by the enumerated value object LC_IceDynamics. The permitted values of the attribute *height* are described by the value object LC_PermittedPosRealValue Other attributes may be established through registration. It has two subtypes: LC_TerresterialIce, 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_Permafrost

The LC_Permafrost metalanguage object is a subtype of LC_WaterBodyAndAssociatedSurfaceElement. 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_PermittedPosRealValue Note that depth is negative to height. Other attributes may be established through registration.

8.16.2.5 LC_TerrestrialIce

The LC_TerrestrialIce metalanguage object is a subtype of LC_Ice. Attributes may 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 terrestrial areas covered with ice.

8.16.2.6 LC_FloatingIce

The LC_FloatingIce metalanguage object is a subtype of LC_Ice. It has three subtypes: LC_SeaIce, LC_LakeIce, and LC_RiverIce. 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 ice.

8.16.2.7 LC_IceDynamics

The code list LC_IceDynamics contains a list of construction status types. This list contains two types: *moving* and *standing*. This list may be extended through registration.

8.16.2.8 LC_WaterBodyDynamics

The code list LC_WaterBodyDynamics contains a list of construction status types. This list contains two types: *flowing* and *standing*. This list may be extended through registration.

8.16.2.9 LC_WaterBodyPositions

The code list LC_WaterBodyPositions contains a list of construction status types. This list contains two types: *aboveSurface* and *belowSurface*. This list may be extended through registration.

8.16.2.10 LC_PermafrostType

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

8.16.2.11 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. 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 may 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.

8.16.2.12 LC_PeriodicVariationType

The code list LC_PeriodicVariationType contains a list types of periodic variations. This list contains four types: *atmospheric*, *daily*, *tidal* and *seasonal*. This list may 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 relation *waterBodyAndAssociatedSurfaceCharacteristic*. The component LC_WaterAndAssociatedSurfacesCharacteristic may 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. This is represented in Figure 14.

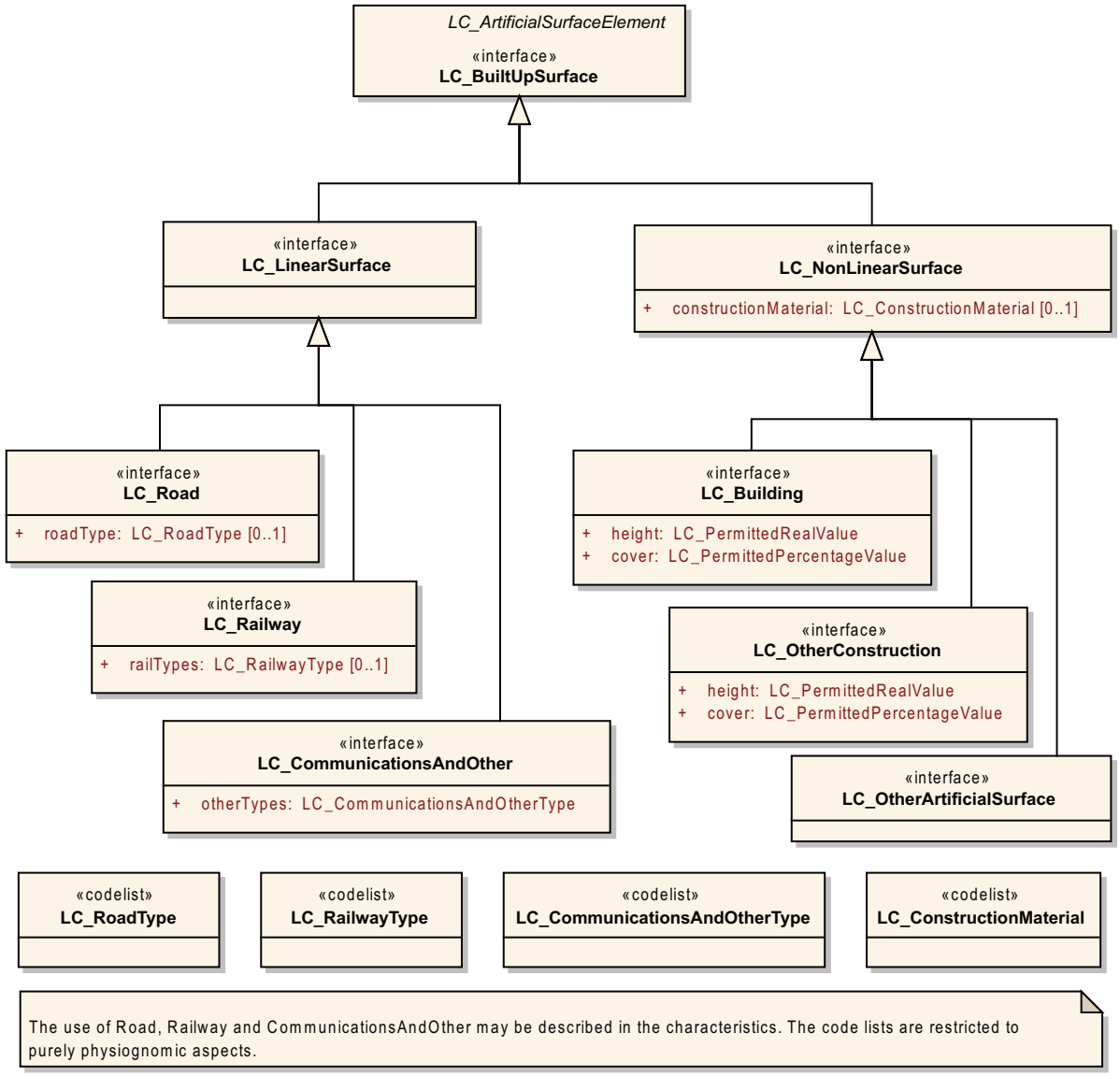


Figure 14 — Subtypes of LC_BuiltUpSurface

8.17.2 LC_BuiltUpSurface classes

8.17.2.1 LC_LinearSurface

The LC_LinearSurface metalanguage object is a subtype of LC_BuiltUpSurface. It has three subtypes: LC_Road, LC_Railway and LC_CommunicationsAndOther. 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 These linear surface objects do not describe land use. In these cases a land use related name is used to identify a particular physiognomic appearance of an artificial land cover. The “use aspect” of a road, a railway and a communication and other linear feature may be described as a characteristic associated with these classes. The enumerations associated with the subclasses are 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. The permitted values of the optional attribute *constructionMaterial* are described by the code list LC_ConstructionMaterial. 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_Road

The LC_Road metalanguage object is a subtype of LC_LinearSurface. The permitted values of the optional attribute *type* are described by the code list LC_RoadType. This metalanguage object, when instantiated, allows the generation of a land cover feature class, in a land cover classification system, for land covered by a road.

NOTE The name “road” is a land-use related name that is used here to represent the physiognomic appearance of a road, not its use as a road.

8.17.2.4 LC_Railway

The LC_Railway metalanguage object is a subtype of LC_LinearSurface. The permitted values of the optional attribute *type* are described by the code list LC_RailwayType. This metalanguage object, when instantiated, allows the generation of a land cover feature class, in a land cover classification system, for land covered by a railway.

NOTE The name “railway” is a land-use related name that is used here to represent the physiognomic appearance of a railway, not its use as a railway.

8.17.2.5 LC_CommunicationsAndOther

The LC_CommunicationsAndOther metalanguage object is a subtype of LC_LinearSurface. The permitted values of the optional attribute *type* are described by the code list LC_CommunicationsAndOtherType. This metalanguage object, when instantiated, allows the generation of a land cover feature class, in a land cover classification system, for land covered by a communication lines, electrical transmission lines and other types of linear artificial land cover.

NOTE The name “CommunicationsAndOther” is a land-use related name that is used here to represent the physiognomic appearance, not its use.

8.17.2.6 LC_Building

The LC_Building metalanguage object is a subtype of LC_NonLinearSurface. It has two attributes: *height* and *cover*. The permitted values of the attribute *height* are described by the value object LC_PermittedRealValue and the permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageValue. 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.

8.17.2.7 LC_OtherConstruction

The LC_OtherConstruction metalanguage object is a subtype of LC_NonLinearSurface. It has two attributes: *height* and *cover*. The permitted values of the attribute *height* are described by the value object LC_PermittedRealValue and the permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageValue. 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.

8.17.2.8 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.

8.17.2.9 LC_RoadType

The code list LC_RoadType contains a list of road types. At the metalanguage level this list is empty, but it may be populated through registration.

8.17.2.10 LC_RailwayType

The code list LC_RailwayType contains a list of railway types. At the metalanguage level this list is empty, but it may be populated through registration.

8.17.2.11 LC_CommunicationsAndOtherType

The code list LC_CommunicationsAndOtherType contains a list of other types. At the metalanguage level this list is empty, but it may be populated through registration.

8.17.2.12 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 may 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_Deposit and LC_Extraction. This is represented in Figure 15.

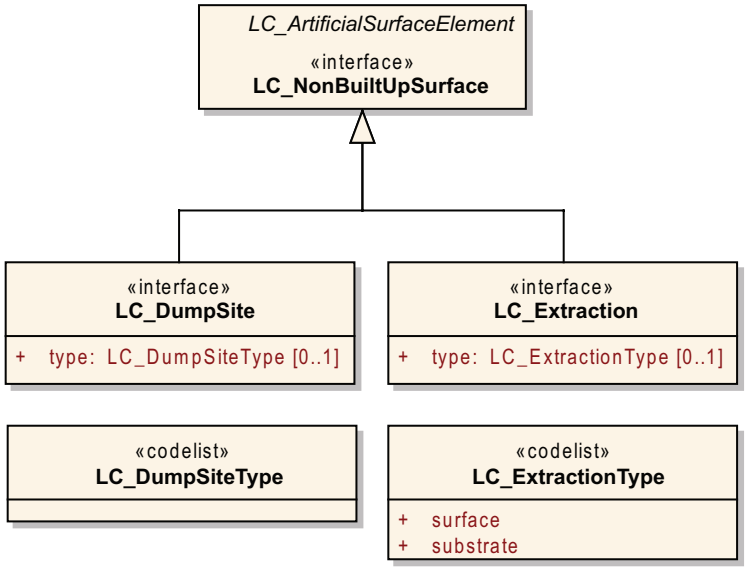


Figure 15 — Subtypes of LC_NonBuiltUpSurface

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.

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.

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 may 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* and *substrate*. This list may 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 16.

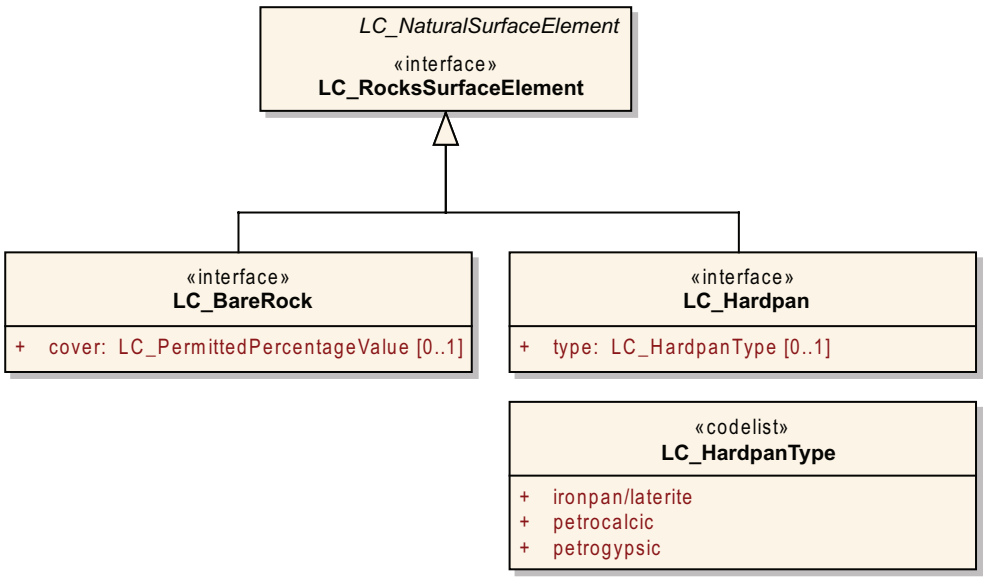


Figure 16 — Subtypes of LC_RocksSurfaceElement

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*. The permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageValue. 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*, *petrocalcic* and *petrogypsic*. This list may 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 17.

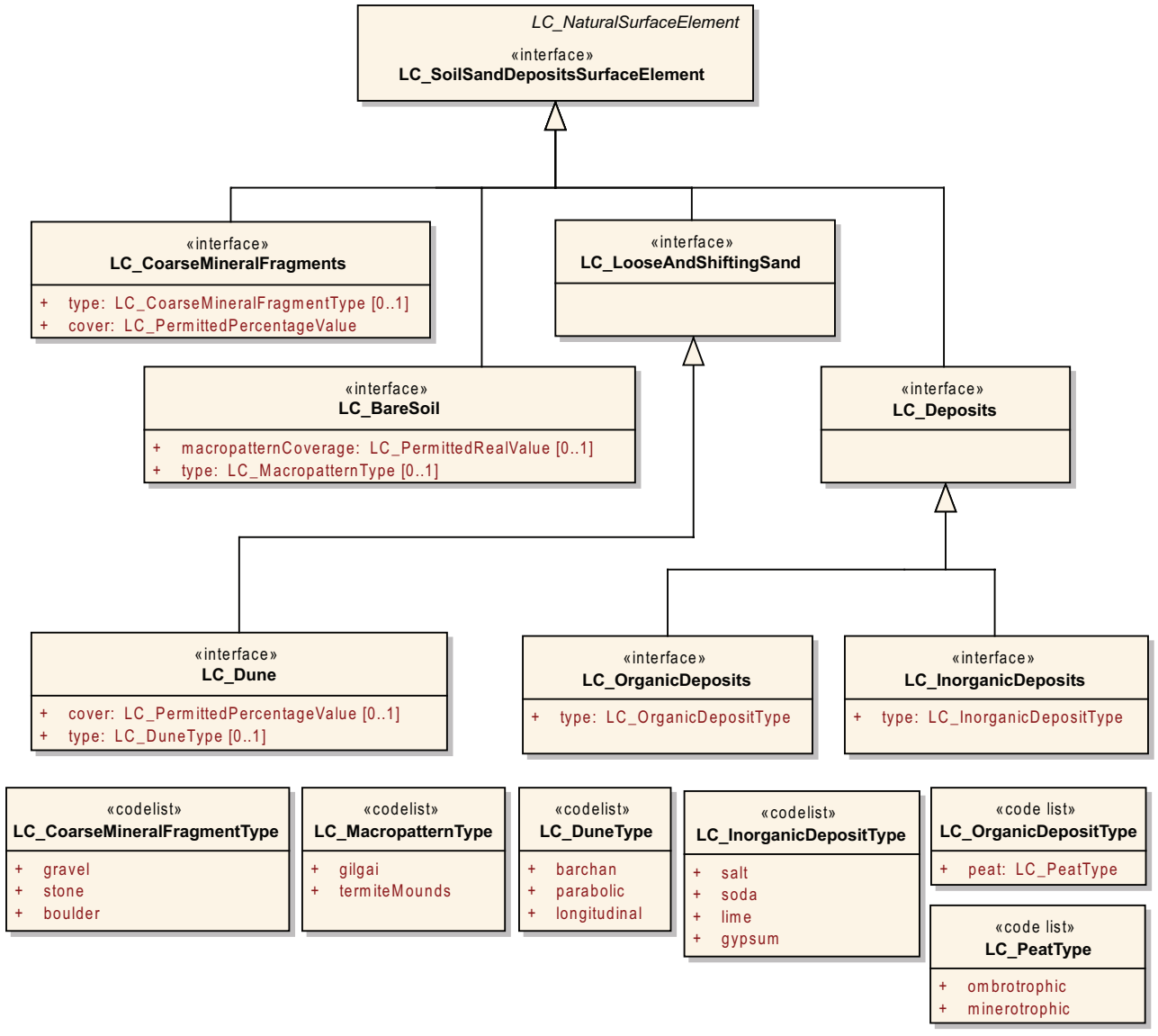


Figure 17 — Subtypes of LC_SoilSandDepositsSurfaceElement

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 two attributes: *cover* and *type*. The permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageValue and the permitted values of the attribute *type* are described by the code list LC_CoarseMineralFragmentType. 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_PermittedPercentageValue. 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 two optional attributes: *cover* and *type*. The permitted values of the attribute *cover* are described by the value object LC_PermittedPercentageValue. The permitted values of the attribute *type* are described by the code list LC_DuneType. 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 three types: *gravel*, *stone* and *boulder*. This list may 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* and *termiteMounds*. This list may 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*, *parabolic* and *longitudinal*. This list may 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*, *soda*, *lime* and *gypsum*. This list may 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 one type: *peat*. This list may be extended through registration. The types of peat may be described by the code list LC_PeatType.

8.20.2.13 LC_PeatType

The code list LC_PeatType contains a list of types of peat deposits. This list contains two types: *ombrothrophic* and *minerothropic*. This list may be extended through registration.

8.21 LC_ClassCharacteristic

8.21.1 LC_ClassCharacteristic subtypes

Additional information may be provided to further refine metalanguage objects within the LCML by the use of Characteristics. A class characteristic is a component aggregated to an entire LC_LandCoverDescriptor metalanguage object. An LC_LandCoverDescriptor 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.

The component LC_ClassCharacteristic is related to LC_LandCoverDescriptor by the relation characteristic. It has five subtypes: LC_Climate, LC_LandForm, LC_GeographicalAspects, LC_TopographicalAspects and LC_SurfaceCharacteristic. This is represented in Figure 18.

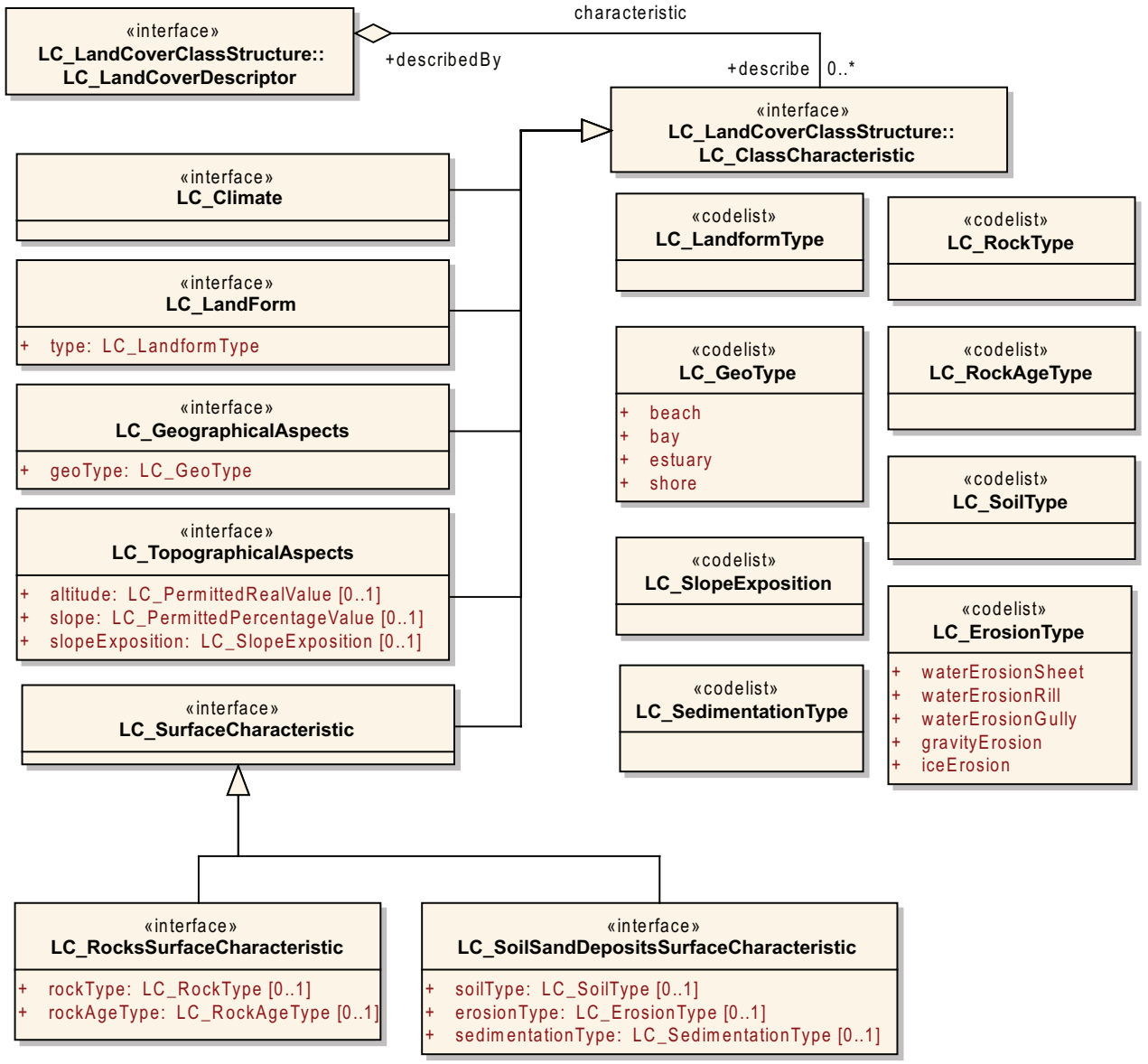


Figure 18 — Subtypes of LC_ClassCharacteristic

8.21.2 LC_ClassCharacteristic classes

8.21.2.1 LC_Climate

The LC_Climate 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 may be used to refine the LC_LandCoverDescriptor 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_LandForm

The LC_LandForm component is a subtype of LC_ClassCharacteristic. It has one attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_LandFormType. This component may be used to refine the LC_LandCoverDescriptor 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_GeographicalAspects

The LC_GeographicalAspects component is a subtype of LC_ClassCharacteristic. It has one attribute: *geoType*. The permitted values of the attribute *geoType* are described by the code list LC_GeoType. This component may 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 class that have a well known geographic type that is not land cover specific.

8.21.2.4 LC_TopographicalAspects

The LC_TopographicalAspects 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_PermittedRealValue. The permitted values of the attribute *slope* are described by the value object LC_PermittedPercentageValue. The permitted values of the attribute *slopeExposition* are described by the code list LC_SlopeExposition. This component may be used to refine the LC_LandCoverDescriptor 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 may be used to refine the LC_LandCoverDescriptor 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 may be used to refine the LC_LandCoverDescriptor 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 may be populated through registration.

8.21.2.9 LC_GeoType

The code list LC_GeoType contains a list of geographicalFacet types. This list contains four types: *beach*, *bay*, *estuary* and *shore*. This list may 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” and “West”. At the metalanguage level this list is empty, but it may 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 may 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 may 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 may 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*, *waterErosionRill*, *waterErosionGully*, *gravityErosion* and *iceErosion*. This list may 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 may be populated through registration.

8.22 LC_LandCoverElementCharacteristic

8.22.1 LC_LandCoverElementCharacteristic subtypes

Additional information may be provided to further refine the individual elements that are assembled to generate an LC_LandCoverDescriptor metalanguage object within the LCML by the use of Element Characteristics. An element characteristic is distinct from a class characteristic in that it applies to a specific LC_Element. Element characteristics may be applied to specific elements or there may be general elements defined related to the generic 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 level of the metalanguage hierarchy at the same time. This is represented in Figure 19.

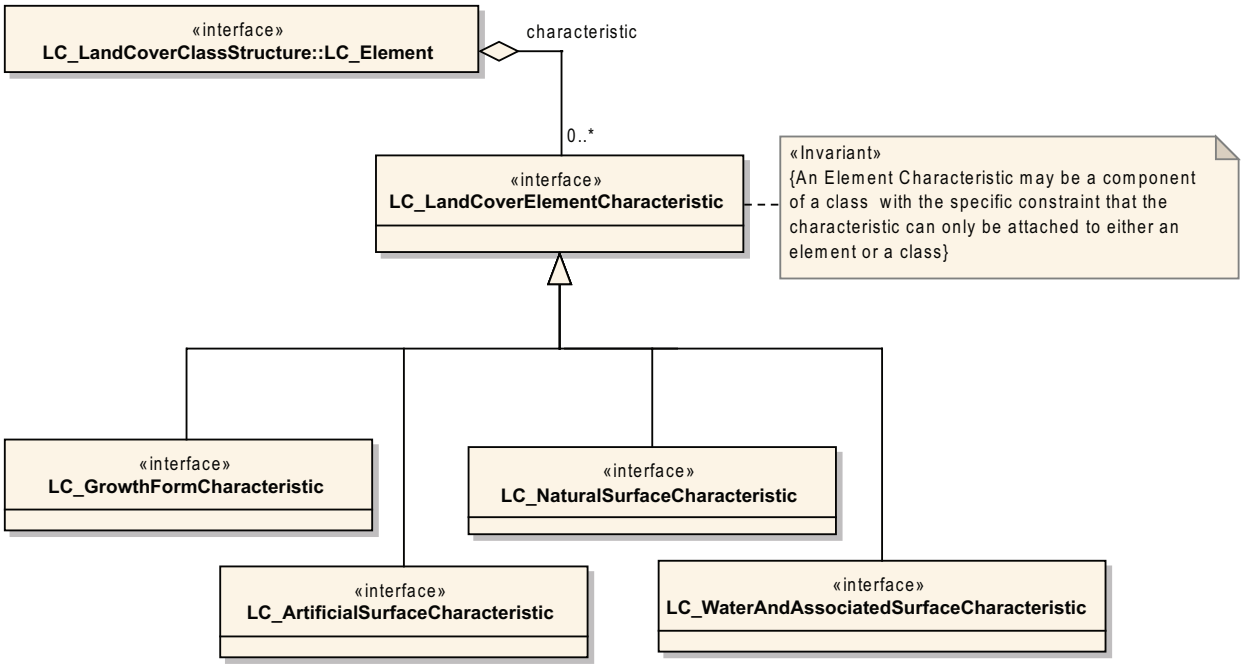


Figure 19 — Subtypes of LC_LandCoverElementCharacteristic

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 may 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 may 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_NaturalSurfaceCharacteristic

The LC_NaturalSurfaceCharacteristic component is a subtype of LC_LandCoverElementCharacteristic. This component may be used to refine the metalanguage object corresponding to an LC_Element object with respect to an natural surface characteristic to permit the generation of a more specific land cover feature class in a land cover classification system. At the metalanguage level this class is empty but may be extended by registration.

8.22.2.4 LC_WaterAndAssociatedSurfaceCharacteristic

The LC_WaterAndAssociatedSurfaceCharacteristic component is a subtype of LC_ LandCoverElementCharacteristic. This component may 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.

8.23 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 may 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 12 subtypes: LC_FloristicAspect, LC_AllometricMeasurement, LC_GrowthFormAge, LC_TreeAreaManagementPractise, LC_BurntStatus, LC_DeadStatus, LC_WaterStress, LC_VegetationDamage, LC_GrowthFormIllness, LC_Grazing, LC_Mowing and LC_VegetationArtificiality. This is represented in Figure 20.

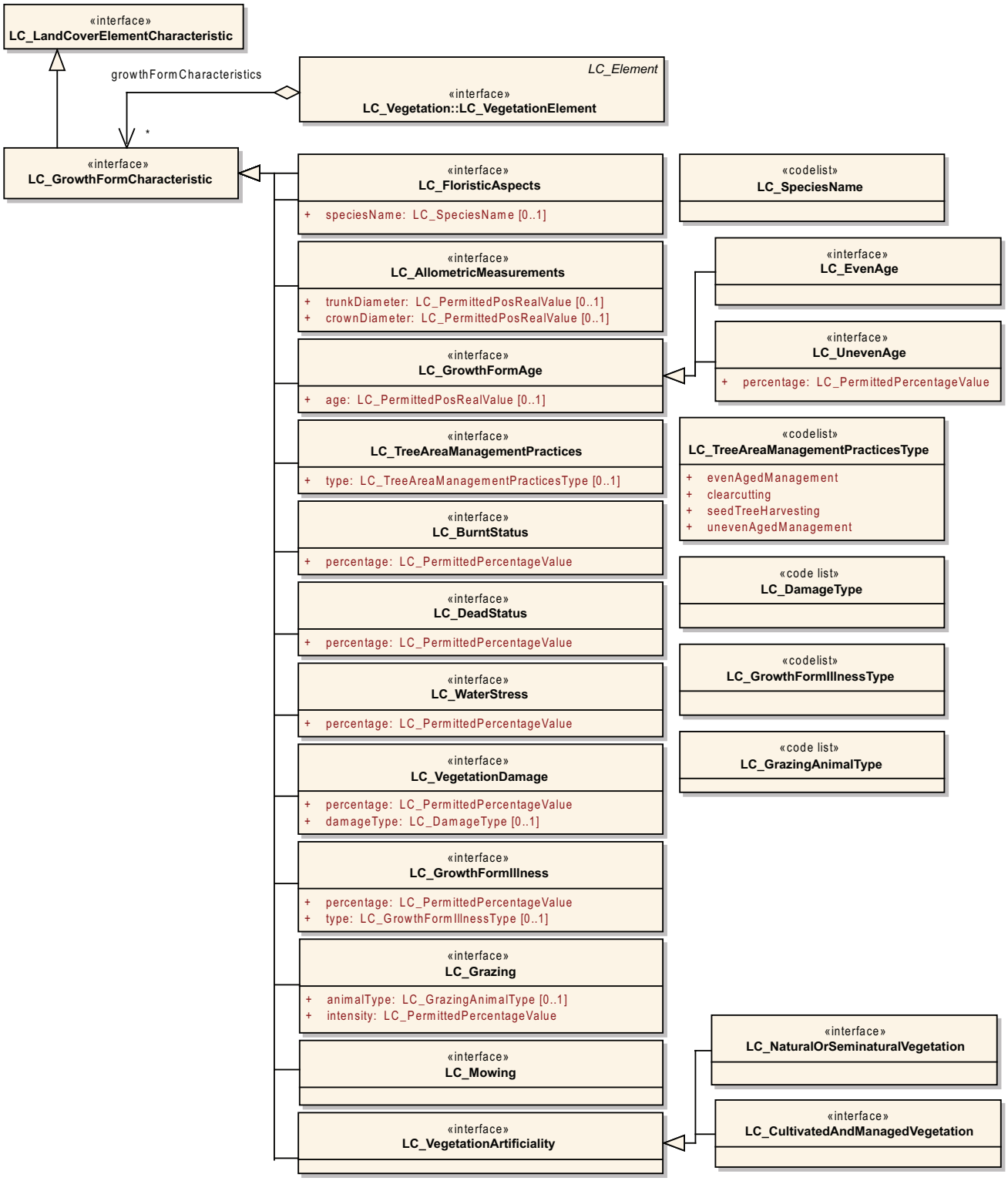


Figure 20 — Subtypes of LC_GrowthFormCharacteristic

8.23.2 LC_GrowthFormCharacteristic classes

8.23.2.1 LC_FloristicAspects

The LC_FloristicAspects 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 may 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.

8.23.2.2 LC_AllometricMeasurements

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_PermittedPosRealValue. The permitted values of the attribute *crownDiameter* are described by the value object LC_PermittedPosRealValue. This component may 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_GrowthFormAge

The LC_GrowthFormAge 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_PermittedPosRealValue. It also has two subtypes: LC_EvenAge and LC_UnevenAge. This component may be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic 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_EvenAge

The LC_EvenAge component is a subtype of LC_GrowthFormAge. This component may be used to refine the metalanguage object corresponding to an LC_GrowthFormAge 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.

8.23.2.5 LC_UnevenAge

The LC_UnevenAge 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_PermittedPercentageValue. This attribute describes the percentage of each group of plants having the same age. This component may be used to refine the metalanguage object corresponding to an LC_GrowthFormAge 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.

8.23.2.6 LC_TreeAreaManagementPractices

The LC_TreeAreaManagementPractices component is a subtype of LC_GrowthFormCharacteristic. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_TreeAreaManagementPracticesType. This component may be used to refine the metalanguage object corresponding to an LC_GrowthFormCharacteristic object with respect to tree management practices, to permit the generation of a more specific land cover feature class in a land cover classification system.

8.23.2.7 LC_BurntStatus

The LC_BurntStatus 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_PermittedPercentageValue. 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 may 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.

8.23.2.8 LC_DeadStatus

The LC_DeadStatus 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_PermittedPercentageValue. This attribute describes the percentage of a growth form which has died. This component may 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.

8.23.2.9 LC_WaterStress

The LC_WaterStress 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_PermittedPercentageValue. This attribute describes the percentage of plants that are water stressed. This component may 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.

8.23.2.10 LC_VegetationDamage

The LC_VegetationDamage 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_PermittedPercentageValue. The permitted values of the attribute *damageType* are described by the enumerated value object LC_VegetationDamageType. This component may 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_GrowthFormIllness

The LC_GrowthFormIllness 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_PermittedPercentageValue. The permitted values of the attribute *type* are described by the code list LC_GrowthFormIllnessType. This component may 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.

8.23.2.12 LC_Grazing

The LC_Grazing component is a subtype of LC_GrowthFormCharacteristic. It has two attributes: *intensity* and optionally *animalType*. This component may 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.

8.23.2.13 LC_Mowing

The LC_Mowing component is a subtype of LC_GrowthFormCharacteristic. This component may 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.

8.23.2.14 LC_VegetationArtificiality

The LC_VegetationArtificiality component is a subtype of LC_GrowthFormCharacteristic. It has two subtypes: LC_NaturalOrSeminaturalVegetation and LC_CultivatedAndManagedVegetation. This component may 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.

8.23.2.15 LC_NaturalOrSeminaturalVegetation

The LC_NaturalOrSeminaturalVegetation component is a subtype of LC_VegetationArtificiality. This component may 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_CultivatedAndManagedVegetation

The LC_CultivatedAndManagedVegetation component is a subtype of LC_VegetationArtificiality. This component may 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.

8.23.2.17 LC_SpeciesName

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

8.23.2.18 LC_TreeAreaManagementPracticesType

The code list LC_TreeAreaManagementPracticesType contains a list of tree management practise types. This list contains four types: *evenAgedManagement*, *clearcutting*, *seedTreeHarvesting* and *unevenAgedManagement*. This list may be extended through registration.

8.23.2.19 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 may be populated through registration.

8.23.2.20 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 may be populated through registration.

8.23.2.21 LC_GrazingAnimalType

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

8.24 LC_NameAttributionCriteria

8.24.1 LC_NameAttributionCriteria subtypes

The LC_NameAttributionCriteria metalanguage object is a component of LC_FloristicAspect through the relationship *nameAttributionCriteria* and has two subtypes: LC_SinglePlantSpecies and LC_GroupOfPlantSpecies. 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 may be used to refine the metalanguage object corresponding to an LC_FloristicAspect 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 21.

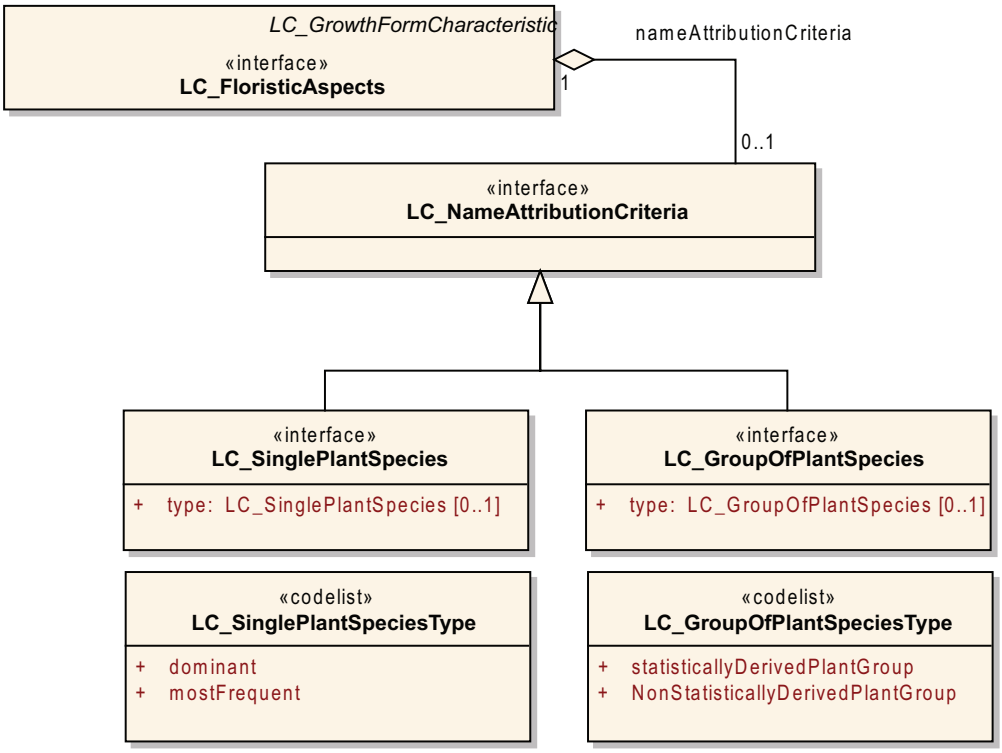


Figure 21 — Subtypes of LC_NameAttributionCriteria

8.24.2 LC_NameAttributionCriteria classes

8.24.2.1 LC_SinglePlantSpecies

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

8.24.2.2 LC_GroupOfPlantSpecies

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

8.24.2.3 LC_SinglePlantSpeciesType

The code list class LC_SinglePlantSpeciesType contains a list of characteristics of plant species naming criteria. This list contains two types: *dominant* and *mostFrequent*. This list may be extended through registration.

8.24.2.4 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* and *nonStatisticallyDerivedPlantGroup*. This list may be extended through registration.

8.25 LC_CultivatedAndManagedVegetation

8.25.1 LC_CultivatedAndManagedVegetation subtypes

The LC_CultivatedAndManagedVegetation component is a subtype of LC_VegetationArtificiality. This component may 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.

CultivatedAndManagedVegetation has 11 subtypes: LC_UrbanPark, LC_CropYield, LC_Plantation, LC_CropGrowingParameter, LC_PlantSpreadingGeometry, LC_WaterSupplyPeriod, LC_FieldSize, LC_MechanicalErosionControl, LC_PestControl, LC_CropFertilization and LC_Ploughing. This is represented in Figure 22.

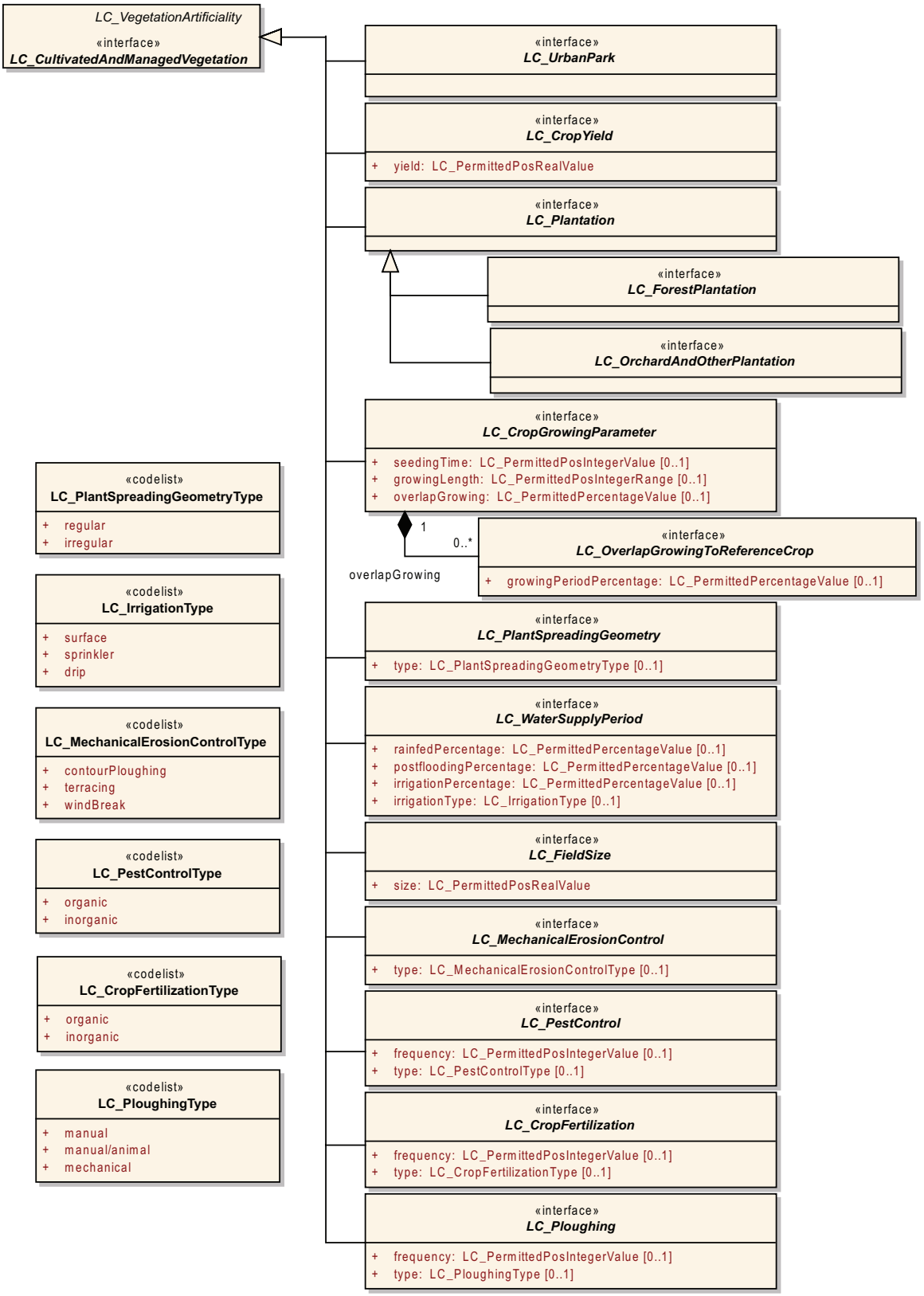


Figure 22 — Subtypes of LC_CultivatedAndManagedVegetation

8.25.2 LC_CultivatedAndManagedVegetation classes

8.25.2.1 LC_UrbanPark

The LC_UrbanPark component metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. This component may be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetation object, by indicating that it is an urban park, to permit the generation of a more specific land cover feature class in a land cover classification system.

8.25.2.2 LC_CropYield

The LC_CropYield component metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has one attribute: *yield*. The permitted values of the attribute *yield* are described by the value object LC_PermittedPosRealValue. This component may 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.

8.25.2.3 LC_Plantation

The LC_Plantation component metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has two subtypes: LC_ForestPlantation and LC_OrchardAndOtherPlantation. This component may 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.

8.25.2.4 LC_ForestPlantation

The LC_ForestPlantation component metalanguage object is a subtype of LC_Plantation. This component may be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetation 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.

8.25.2.5 LC_OrchardAndOtherPlantation

The LC_OrchardAndOtherPlantation component metalanguage object is a subtype of LC_Plantation. This component may be used to refine the metalanguage object corresponding to an LC_CultivatedAndManagedVegetation 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.

8.25.2.6 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_PermittedPosIntegerValue. The permitted values of the attributes *growingLength* are described by the value object LC_PosIntegerRange. The permitted values of the attribute *overlapGrowing* are described by the value object LC_PermittedPercentageValue. This component may 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_OverlapGrowingToReferenceCrop

The component LC_OverlapGrowingToReferenceCrop is related to LC_CropGrowingParameter 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_PermittedPercentageValue. The component LC_OverlapGrowingToReferenceCrop may be used to refine the metalanguage object LC_CropGrowingParameter to permit the generation of a more specific land cover feature class in a land cover classification system.

8.25.2.8 LC_PlantSpreadingGeometry

The LC_PlantSpreadingGeometry metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_PlantSpreadingGeometryType. This component may 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.

8.25.2.9 LC_WaterSupplyPeriod

The LC_WaterSupplyPeriod metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. 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_PermittedPercentageValue. The permitted values of the attribute *type* are described by the code list LC_IrrigationType. This component may 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.

8.25.2.10 LC_FieldSize

The LC_FieldSize metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has one attribute: *size*. The permitted values of the attribute *size* are described by the value object LC_PermittedPosRealValue. This component may 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.

8.25.2.11 LC_MechanicalErosionControl

The LC_MechanicalErosionControl metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_MechanicalErosionControlType. This component may 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.

8.25.2.12 LC_PestControl

The LC_PestControl metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has two optional attributes: *frequency* and *type*. The permitted values of the attribute *frequency* are described by the value object LC_PermittedPosIntegerValue. The permitted values of the attribute *type* are described by the code list LC_PestControlType. This component may 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.

8.25.2.13 LC_CropFertilization

The LC_CropFertilization metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has two optional attributes: *frequency* and *type*. The permitted values of the attribute *frequency* are described by the value object LC_PermittedPosIntegerValue. The permitted values of the attribute *type* are described by the code list LC_CropFertilizationType. This component may 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.

8.25.2.14 LC_Ploughing

The LC_Ploughing metalanguage object is a subtype of LC_CultivatedAndManagedVegetation. It has two optional attributes: *frequency* and *type*. The permitted values of the attribute *frequency* are described by the value object LC_PermittedPosIntegerValue. The permitted values of the attribute *type* are described by the code list LC_PloughingType. This component may 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.

8.25.2.15 LC_PlantSpreadingGeometryType

The code list LC_PlantSpreadingGeometryType contains a list of types of plant spreading geometry. This list contains two types: *regular* and *irregular*. This list may be extended through registration.

8.25.2.16 LC_IrrigationType

The code list LC_IrrigationType contains a list of irrigation types. This list contains three types: *surface*, *sprinkler* and *drip*. This list may be extended through registration.

8.25.2.17 LC_MechanicalErosionControlType

The code list LC_MechanicalErosionControlType contains a list of mechanical erosion control types. This list contains three types: *contourPloughing*, *terracing* and *windBreak*. This list may be extended through registration.

8.25.2.18 LC_PestControlType

The code list LC_PestControlType contains a list of pest control types. This list contains two types: *organic* and *inorganic*. This list may be extended through registration.

8.25.2.19 LC_CropFertilizationType

The code list LC_CropFertilizationType contains a list of types of crop fertilization types. This list contains two types: *organic* and *inorganic*. This list may be extended through registration.

8.25.2.20 LC_PloughingType

The code list LC_PloughingType contains a list of ploughing types. This list contains three types: *manual*, *manual/animal* and *mechanical*. This list may 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 two subtypes: LC_ConstructionStatus and LC_ConstructionUse. The component LC_ArtificialSurfaceCharacteristic may 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 23.

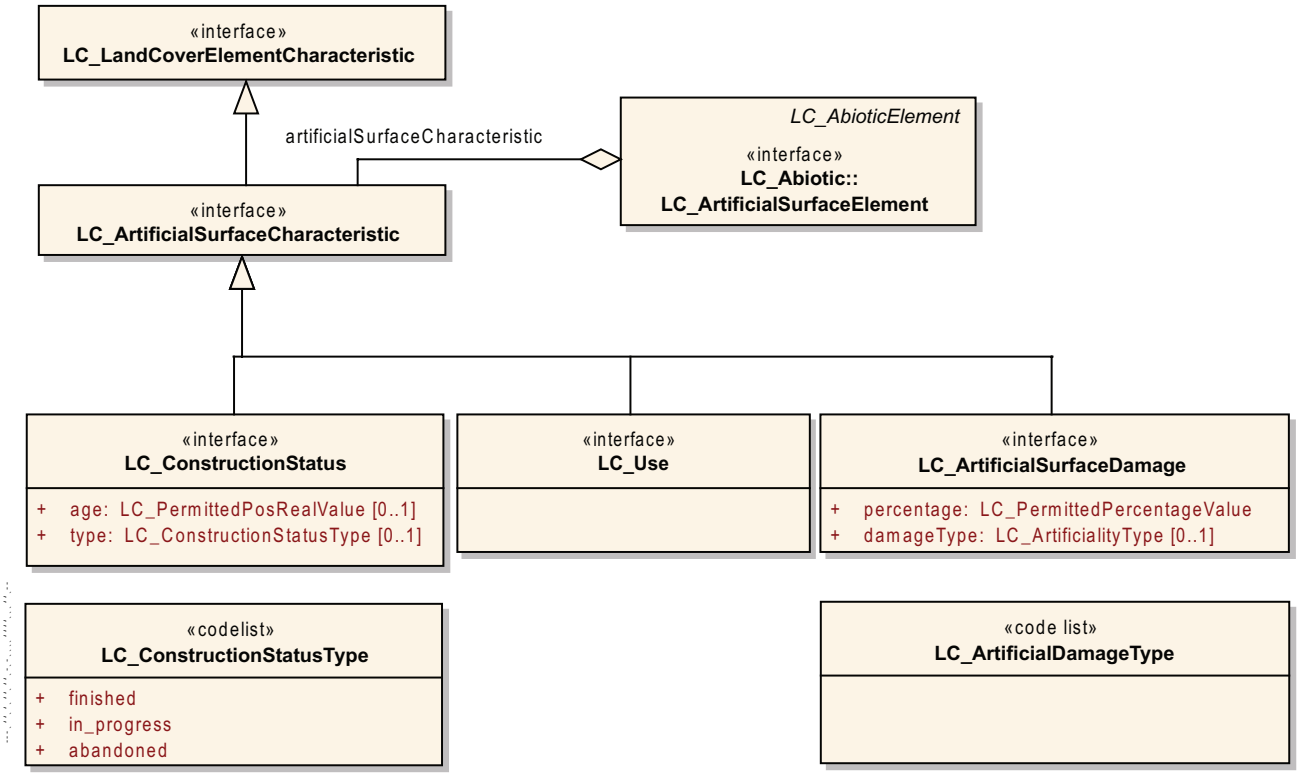


Figure 23 — Subtypes of LC_ArtificialSurfaceCharacteristic

8.26.2 LC_ArtificialSurfaceCharacteristic classes

8.26.2.1 LC_ConstructionStatus

The LC_ConstructionStatus 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_PermittedPosRealValue. The permitted values of the attribute *type* are described by the code list LC_ConstructionStatusType. This component may be used to refine the metalanguage object corresponding to an LC_ArtificialSurfaceCharacteristic class to permit the generation of a more specific land cover feature class in a land cover classification system.

8.26.2.2 LC_Use

The LC_Use component is a subtype of LC_ArtificialSurfaceCharacteristic. The different ways of describing use are user defined. Attributes may be established through registration. This component may be used to refine the metalanguage object corresponding to an entire LC_ArtificialSurfaceCharacteristic object to permit the generation of a more specific land cover feature class in a land cover classification system.

8.26.2.3 LC_ArtificialSurfaceDamage

The LC_ArtificialSurfaceDamage 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_PermittedPercentageValue. The permitted values of the attribute *damageType* are described by the enumerated value object LC_ArtificialDamageType. This component may 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 may be populated through registration.

8.26.2.5 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* and *abandoned*. This list may 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 six subtypes: LC_Aquaculture, LC_Artificiality, LC_WaterSalinity, LC_SnowCategory, LC_IceCategory and LC_WaterChemistry. The component LC_WaterAndAssociatedSurfaceCharacteristic may 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 24.

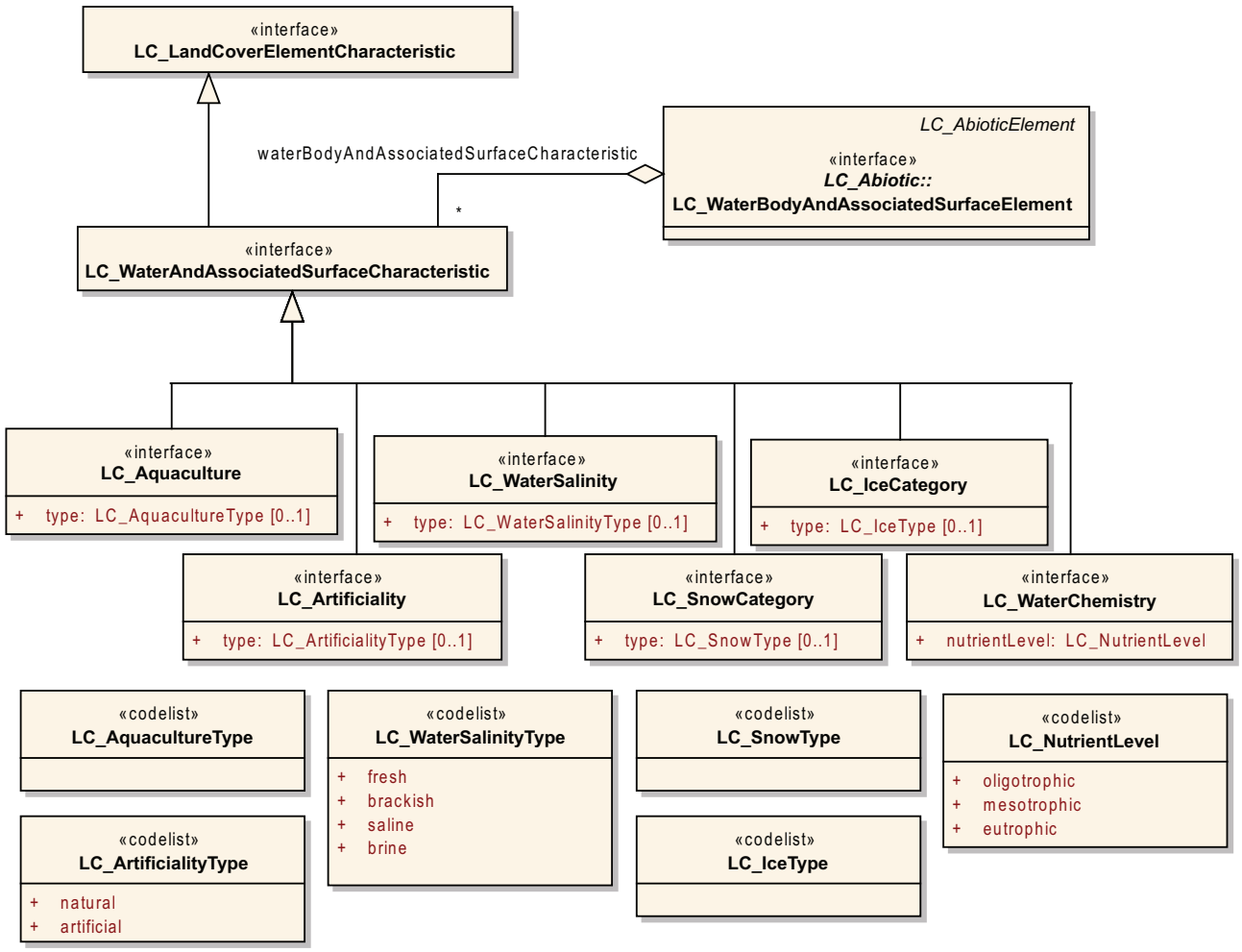


Figure 24 — Subtypes of LC_WaterAndAssociatedSurfaceCharacteristic

8.27.2 LC_WaterAndAssociatedSurfaceCharacteristic classes

8.27.2.1 LC_Aquaculture

The LC_Aquaculture component metalanguage object is a subtype of LC_WaterAndAssociatedSurfaceCharacteristic component. It has one optional attribute: *type*. The permitted values of the attribute *type* are described by the code list LC_AquacultureType. The component LC_Aquaculture may 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.

8.27.2.2 LC_Artificiality

The LC_Artificiality 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 may 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.

8.27.2.3 LC_WaterSalinity

The LC_WaterSalinity 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 may 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.

8.27.2.4 LC_SnowCategory

The LC_SnowCategory 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 may 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.

8.27.2.5 LC_IceCategory

The LC_IceCategory 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 may 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.

8.27.2.6 LC_WaterChemistry

The LC_WaterChemistry 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 may be used to refine the LC_WaterBodyAndAssociatedSurfaceElement to permit the generation of a more specific land cover feature class in a land cover classification system.

8.27.2.7 LC_AquacultureType

The code list LC_AquacultureType contains a list of aquaculture types. At the metalanguage level this list is empty, but it may be populated through registration.

8.27.2.8 LC_ArtificialityType

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

8.27.2.9 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 may be extended through registration.

8.27.2.10 LC_SnowType

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

8.27.2.11 LC_IceType

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

8.27.2.12 LC_NutrientLevel

The code list LC_NutrientLevel contains a list of nutrient levels. This list contains three types: *oligotrophic*, *mesotrophic* and *eutrophic*. This list may 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 numeric values at the metalanguage level maybe instantiated to the basic number types at the type level. The basic number types are defined in ISO/TS 19103 and are required for implementation of this part of ISO 19144. 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 has 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 may be represented by the value object. This is represented in Figure 25.

The LC_PermittedPosRealValue, LC_PermittedPercentageValue and LC_PermittedPosIntegerValue objects may 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/TS 19103. The results of instantiating a classification system are objects that carry actual values. In the various examples given in this part of ISO 19144, 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.

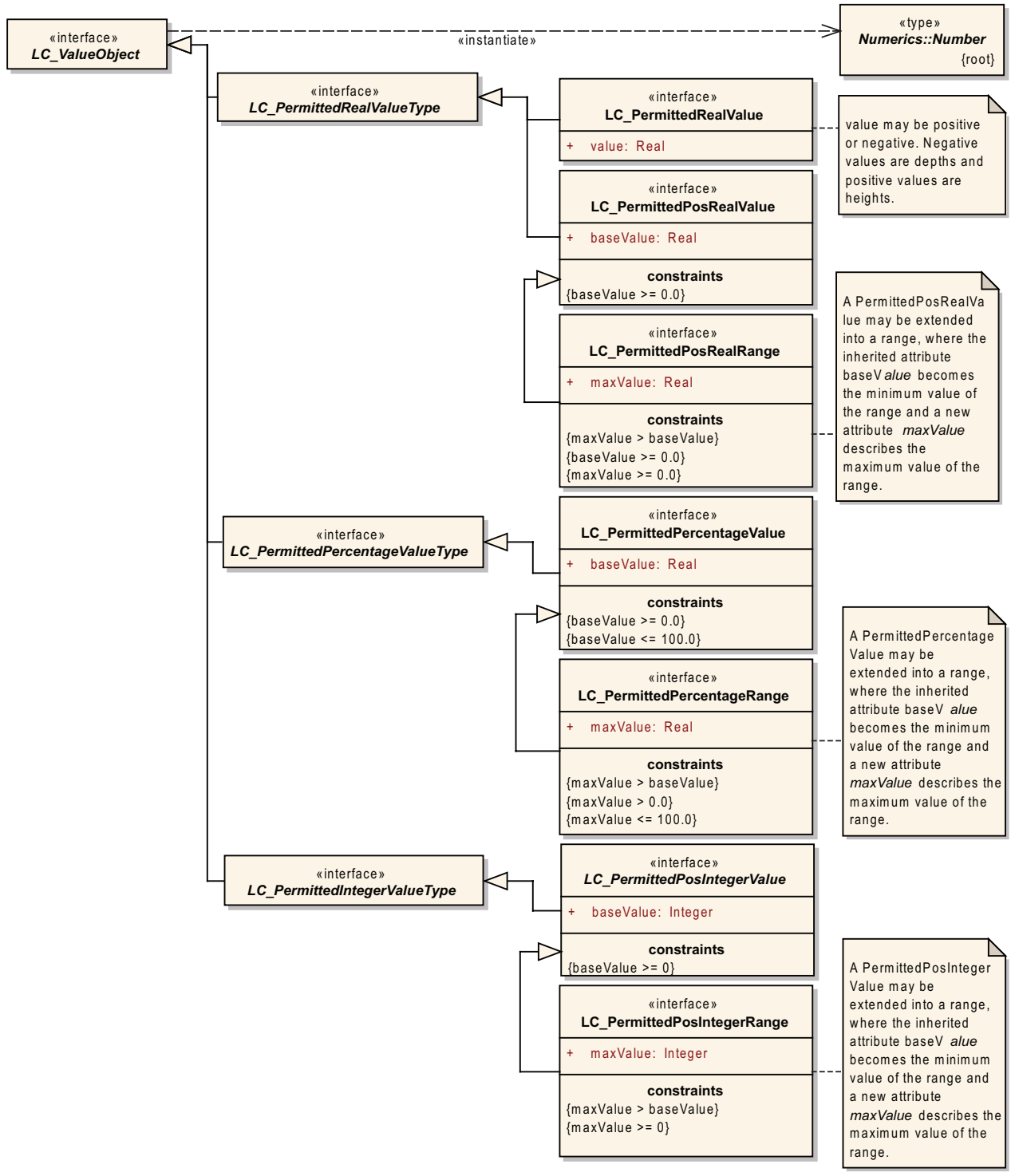


Figure 25 — LC_ValueObject

8.28.2 LC_ValueObject types

8.28.2.1 LC_ValueObject

LCML defines a set of value objects at the metalanguage level that may 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/TS 19103 defined basicTypes.

It has three subtypes: *LC_PermittedRealValueType*, *LC_PermittedPercentageValueType*, and *LC_PermittedIntegerValueType*.

8.28.2.2 Number

Number is a class from the ISO/TS 19103 basicTypes package to which the subtypes of *LC_ValueObject* may 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 may be instantiated as a real number types using the Real type from the basic Primitive Types package in ISO/TS 19103, with constraints. It has three subtypes: LC_PermittedRealValue, LC_PermittedPosRealValue and indirectly LC_PermittedPosRealRange.

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* may be instantiated as a real number type using the Real type from the basic Primitive Types package in ISO/TS 19103, where the value may be positive or negative. The sign convention is that negative values are depths and positive values are heights.

8.28.2.5 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* may be instantiated as a real number type using the Real type from the basic Primitive Types package in ISO/TS 19103, with the constraint: {*baseValue* $>=$ 0.0}.

8.28.2.6 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* may be instantiated as a pair of real number types using the Real type from the basic Primitive Types package in ISO/TS 19103, with the constraints:

{*maxValue* $>$ *baseValue*

and

baseValue $>=$ 0.0

and

maxValue $>=$ 0.0}

8.28.2.7 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 may be instantiated as a real number types using the Real type from the basic Primitive Types package in ISO/TS 19103, with constraints. It has two subtypes: LC_PermittedPercentageValueType, and indirectly LC_PermittedPercentageRange.

8.28.2.8 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* may be instantiated as an integer number type using the Integer type from the basic Primitive Types package in ISO/TS 19103, with the constraint:

{*baseValue* >= 0.0}

and

baseValue <= 100.0}.

8.28.2.9 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* may be instantiated as a pair of real number types using the Real type from the basic Primitive Types package in ISO/TS 19103, with the constraints:

{*maxValue* > *baseValue*

and

maxValue >= 0 and *maxValue* <= 100.0}.

8.28.2.10 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 which may be instantiated as an integer number type using the Integer type from the basic Primitive Types package in ISO/TS 19103, with constraints. It has two subtypes: *LC_PermittedPosIntegerValueType*, and indirectly LC_PermittedPosIntegerRange.

8.28.2.11 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* may be instantiated as a integer number type using the Integer type from the basic Primitive Types package in ISO/TS 19103, with the constraint: {*baseValue* >= 0}.

8.28.2.12 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* may be instantiated as a pair of integer number types using the Integer type from the basic Primitive Types package in ISO/TS 19103, with the constraints:

{*maxValue* > *baseValue*

and

maxValue >= 0}.

9 Extension of the LCML

9.1 Introduction

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 class LC_Element in the model used to express the metalanguage, shall only be allowed to be changed by amendment of this part of ISO 19144. This allows for a route to extend the language that is well controlled by the standardization process.

Changes to the properties land cover element characteristics and land cover class characteristics as expressed in the metalanguage objects LC_LandCoverElementCharacteristic and LC_LandCoverClassStructure may be done by registration in conformance with the registration rules described in Clause 9. This provides a simpler 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 may also be made to the subtypes of the class LC_Element or the components, attributes or code lists associated with these metalanguage objects by registration. This is addition to the subtypes of LC_ Element, not change.

This part of ISO 19144 defines the structure of the register, not its contents. The contents may be established by a national body or other user of this part of ISO 19144 who would establish their own instance of the register. A user of this part of ISO 19144 could make a perfect description of their national land cover classification system using the elements defined in this part of ISO 19144 plus additional registered extensions. A comparison of the two land cover classification systems using the LCML would be based on the common elements defined in this part of ISO 19144 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 might 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 part of ISO 19144, 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 described in Clause 9 is different in purpose from the register described in ISO 19144-1. The register in ISO 19144-1 is used to record the legend classes produced from a land cover classification system. The register in Clause 9 is at a different level. It is used to manage any extensions to the metalanguage objects in the LCML or changes to the characteristics.

9.2 Backward compatibility

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. Any change shall be backward compatible. None of the metalanguage objects may be deleted from the model. They may be extended with additional UML attributes. If a subobject needs to be altered an additional subobject may 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.

EXAMPLE If a code list is extended the old version of the code list is superseded with a new object containing the complete 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 class and the deprecated class shall 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 may only be changed by amendment to this part of ISO 19144, and for changes to the metalanguage objects LC_ElementCharacteristic and LC_ClassCharacteristic which may be done by registration.

The register shall contain a version number that shall be incremented with any change. Changes to the standard by amendment shall be tracked by the version and amendment number of the standard.

9.3 LCML register structure

9.3.1 Elements of the registers

The schema specified in Clause 9 describes the structure of a register for the extension and maintenance of the properties of the LCML as expressed in the metalanguage objects LC_ElementCharacteristic and LC_ ClassCharacteristic and the extension only of LC_Element. The register for the LCML is a multipart register as defined in ISO 19135:2005, 7.1.3 in which several item classes are registered. The item classes are:

a) LC_ClassCharacteristicDescriptorItem – a description of an additional or revised subtype of the metalanguage object LC_ClassCharacteristic that provides general attributes to a land cover metalanguage object.

b) LC_ElementCharacteristicDescriptorItem – a description of an additional or revised subtype of the metalanguage object LC_ElementCharacteristic that provides particular attributes to a land cover metalanguage element (a subtype of LC_Element).

c) LC_ElementDescriptorItem – a description of an additional subtype of LC_Element or any of its already defined subtypes that allows for an additional refinement of an LC_Element subtype. The standardized subtypes of LC_Element shall not be changed through registration, only added to.

9.3.2 Register schema

The LCML register schema is derived from the register schema in ISO 19135 and is shown in Figure 26. The register schema is extended to include a subtype of RE_Register for a LCML register (LC_ LCMLRegister), a subtype of RE_RegisteredItem corresponding to LC_ClassCharacteristicDescriptorItem, LC_ElementCharacteristicDescriptorItem and LC_ElementDescriptorItem and a subtype of RE_ItemClass corresponding LC_ClassCharacteristicDescriptorClass, LC_ElementCharacteristicDescriptorClass and LC_ ElementDescriptorClass.

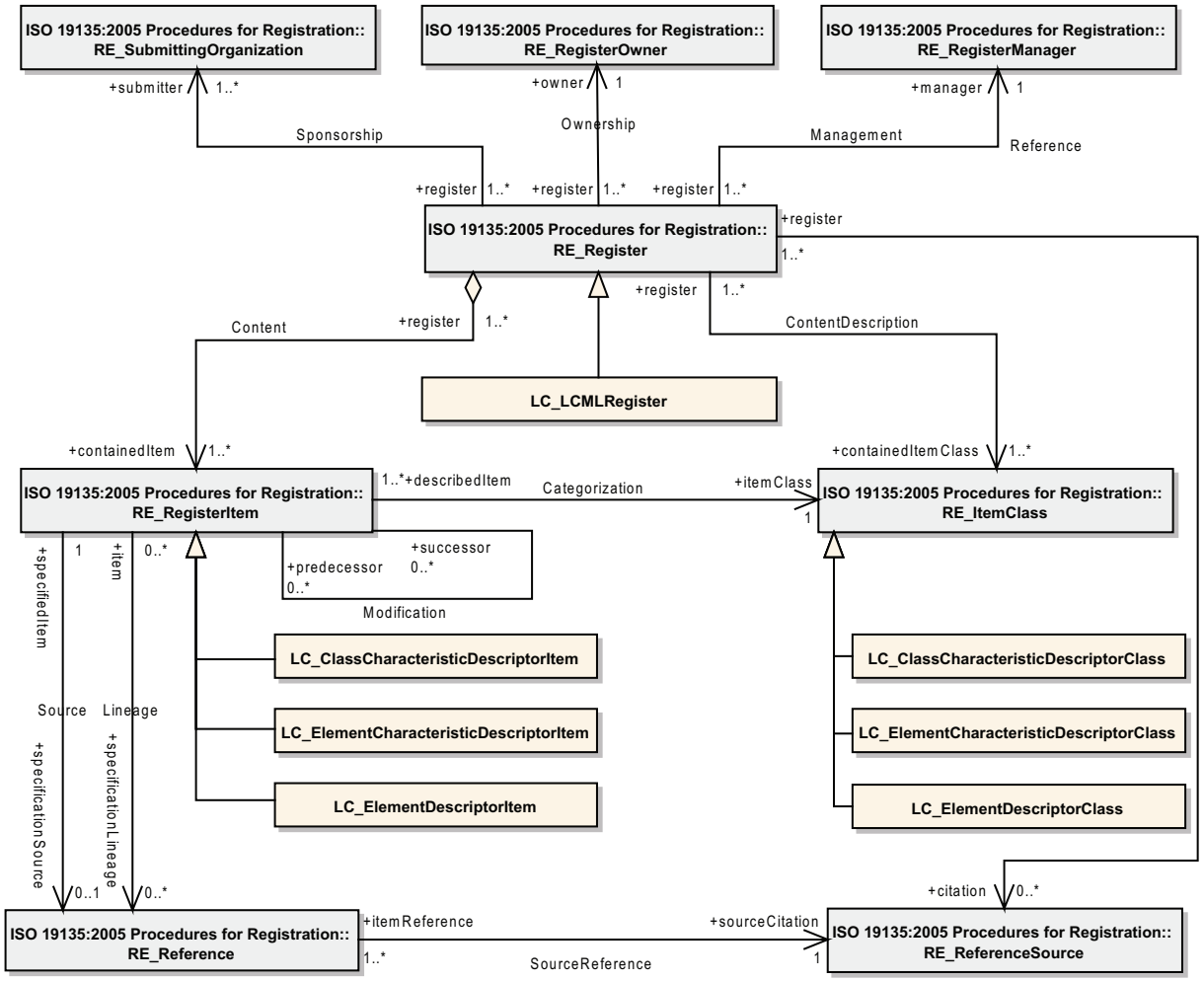


Figure 26 — LCML register schema showing added classes

9.3.3 LCML register

9.3.3.1 LC_LCMLRegister

The class LC_LCMLRegister specifies information about the register itself. It is a subclass of the class RE_Register which is defined in ISO 19135. It inherits 6 attributes from ISO 19135. This is illustrated in Figure 27. Two of the attributes are specialized below in 9.3.3.2 and 9.3.3.3. The other attributes are taken directly from ISO 19135.

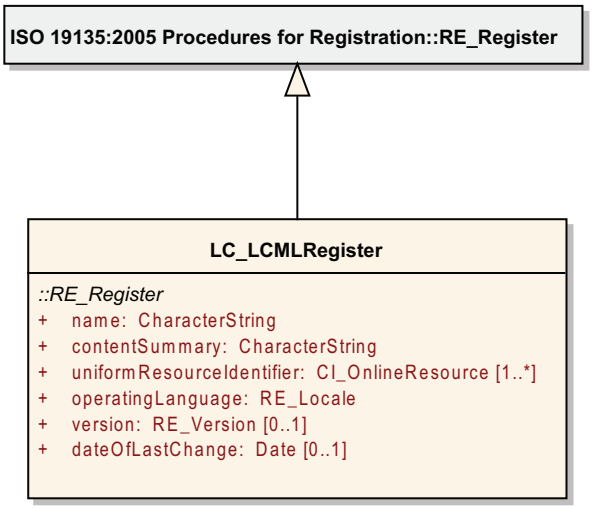


Figure 27 — LCML Register

9.3.3.2 name

ISO 19135 specifies that the attribute *name* shall be a character string that is used to uniquely identify a register within the set of registers maintained by the register owner. In the case the LCML register shall be called:

“Land Cover Meta Language Register”

9.3.3.3 contentSummary

ISO 19135 specifies that the attribute *contentSummary* shall be a character string containing a general statement of the purpose for which items in the register are made, including any limits to the scope of the register, and the types of applications for which the items are intended. In this case the LCML register *contentSummary* shall contain:

“Register of LCML metalanguage objects used to extend the LCML metalanguage LC_ElementCharacteristic and LC_ClassCharacteristic and the extension only of LC_Element”.

9.3.4 Registered Items

9.3.4.1 Registered Item

The class RE_RegisterItem specifies elements of information to be recorded for each item held in a register. It has nine attributes and three associations. The attributes are taken directly from ISO 19135. The associations are to three subtypes.

The three subtypes to RE_RegisteredItem are LC_ClassCharacteristicDescriptorItem, LC_ ElementCharacteristicDescriptorItem and LC_ElementDescriptorItem. These subtypes take the same form and include the following attributes:

a) A definition of the registered LCML metalanguage object;

b) A description of any metalanguage object attributes to the LCML metalanguage object;

c) A reference to the parent class in the LCML metalanguage model (either from the standard or another registered class) together with an indication of the type of relationship such as: subtype, component, enumeration, code list;

d) A reference to any LCML metalanguage object which this metalanguage object supersedes (i.e. causes to be deprecated).

NOTE LC_Element objects may only be extended; that is, an instance of the registered item may be superseded only by another instance that contains all of the information from the superseded registered item.

This is shown in Figure 28.

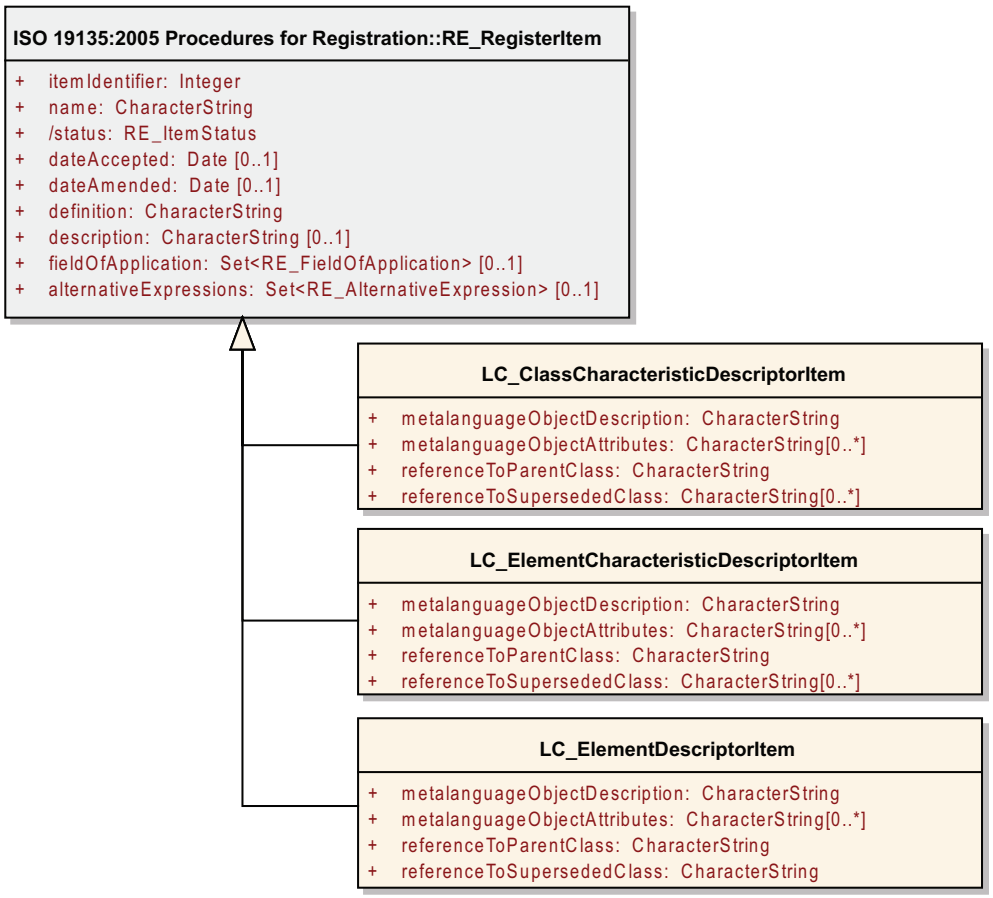


Figure 28 — Registered Item

9.3.4.2 name

The attribute *name* shall be the name of the registered LCML metalanguage object expressed as a character string. The name shall be a unique UML class name using the naming convention for classes in the LCML metalanguage model.

Registered class names used for the extension of subtypes of LC_Element, LC_ClassCharacteristic or LC_ElementCharacteristic objects shall be unique within the register.

9.3.4.3 metalanguageObjectDescription

The attribute *metalanguageObjectDescription* shall be a description of the LCML metalanguage object expressed as a character string.

9.3.4.4 metalanguageObjectAttributes

The optional attribute *metalanguageObjectAttributes* shall be a description of each of the attributes that form part of the LCML metalanguage object described in the attribute *metalanguageObjectDescription* expressed as a set of character strings.

9.3.4.5 referenceToParentClass

The attribute *referenceToParentClass* shall be a character string that contains the name of the parent class to which the registered metalanguage object related, (either from the standard or another registered class) together with an indication of the type of relationship The reference is by object name using the UML object name in the UML model of the LCML.

9.3.4.6 referenceToSupersededClass

The optional attribute *referenceToSupersededClass* shall be a character string or set of character strings that contains the name of the object or objects to which the register metalanguage object supersedes. The reference is by object name using the UML object name in the UML model of the LCML.

9.3.5 Item classes

9.3.5.1 LCML item classes

This registered item specifies information about what can be registered. The three items that may be registered in the LCML register are represented as subclasses of RE_ItemClass. This is illustrated in Figure 29.

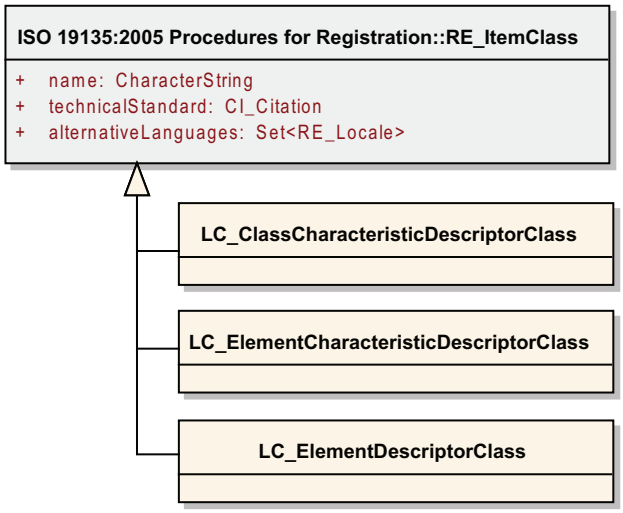


Figure 29 — Classification Item Classes

9.3.5.2 LC_ClassCharacteristicDescriptorClass

This class inherits three attributes: name, technicalStandard and alternativeLanguages.

For the LCML register described in this part of ISO 19144 the attribute “name” shall contain the text string “LC_MetalanguageCharacteristicDescriptorClass” to identify the registered item class.

The attribute “technicalStandard” shall contain the following:

i) *title*: “ISO 19144-2, Geographic information — Classification systems — Part 2: Land Cover Meta Language (LCML)”

ii) *alternateTitle*: “ISO 19144-2”

iii) *date*: “2012”

iv) *otherCitationDetails*: “ISO 19144-2:2012, 9.3”

The attribute “alternativeLanguages” is optional.

9.3.5.3 LC_ElementCharacteristicDescriptorClass

This class inherits three attributes: name, technicalStandard and alternativeLanguages.

For the land cover classification system register described in this part of ISO 19144 the attribute “name” shall contains the text string “LC_ElementCharacteristicDescriptorClass” to identify the registered class.

The attribute “technicalStandard” shall contain the following:

i) *title*: “ISO 19144-2, Geographic information — Classification systems — Part 2: Land Cover Meta Language (LCML)”

ii) *alternateTitle*: “ISO 19144-2”

iii) *date*: “2012”

iv) *otherCitationDetails*: “ISO 19144-2:2012, 9.3”

The attribute “alternativeLanguages” is optional.

9.3.5.4 LC_ElementDescriptorClass

This class inherits three attributes: name, technicalStandard and alternativeLanguages.

For the land cover classification system register described in this part of ISO 19144 the attribute “name” shall contains the text string “LC_ElementDescriptorClass” to identify the registered class.

The attribute “technicalStandard” shall contain the following:

i) *title*: “ISO 19144-2, Geographic information — Classification systems — Part 2: Land Cover Meta Language (LCML)”

ii) *alternateTitle*: “ISO 19144-2”

iii) *date*: “2012”

iv) *otherCitationDetails*: “ISO 19144-2:2012, 9.3”

The attribute “alternativeLanguages” is optional.

Annex A
(normative)

Abstract test suite

A.1 Introduction

This normative annex presents the abstract test suite for evaluating conformance to this part of ISO 19144. The abstract test suite contains a test module for a Classification System (A.2), a test module for a register of metaclasses for the extension of the LCML (A.3) and a test module for the comparison of two land cover classification systems (A.4).

A.2 Conformance of a land cover classification system

a) Test Purpose: Verify that a land cover classification system may be described in terms of the LCML.

b) Test Method: Inspect the generated model of the land cover classification system by composing land cover metaclasses (LC_LandCoverDescriptor) for each class from the land cover classification system and then instantiating each class to form the land cover classification system model. Each 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_LandCoverDescriptor classes.

c) Reference: Clause 8, including the land cover high level 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 – 8.20, and the applicable characteristics as defined in 8.21 – 8.28.

d) Test Type: Capability.

A.3 Conformance of a register for the extension of the metalanguage

A.3.1 Register content

a) Test Purpose: Verify that the items in the register contain the minimum specified content.

b) Test Method: Inspect each of the entries in the register to ensure that they include all elements of information required by the RE_Item class (from ISO 19135) together with the additional attributes defined in the classes LC_ClassCharacteristicDescriptorItem, LC_ElementCharacteristicDescriptorItem and LC_ElementDescriptorItem as required in by Clause 9.

c) Reference: 9.3.4.

d) Test type: Capability.

A.3.2 Test case for uniqueness of registered metaclass names

a) Test purpose: Verify the uniqueness of name values used within the register for subtypes of LC_Element, LC_ClassCharacteristic or LC_ElementCharacteristic classes.

b) Test method: For each item class in the register, check each item; no name shall appear more than once where the item status is “valid”.

c) Reference: 9.3.4.2.

d) Test type: Capability.

A.3.3 Test case for backward compatibility

a) Test purpose: Verify that any changes to the LC_Element, LC_ClassCharacteristic or LC_ ElementCharacteristic classes do not generate an incompatibility with earlier versions of the registered or standardized items.

b) Test method: For each new registered item verify that any class that it modifies or supersedes is marked as invalid and that the new registered item references the superseded item.

c) Reference: 9.2 and ISO 19135.

d) Test type: Capability.

A.4 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. 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_LandCoverDescriptor) for each class from each of the two land cover classification systems and then instantiating each class to form two separate land cover classification systems models. Each 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_LandCoverDescriptor 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 class structure as defined in 8.3, and the definition of the LC_Elements as defined in 8.4 including all of the subtypes of LC_Element defined in 8.5 to 8.16, and the applicable characteristics as defined in 8.17 to 8.24.

d) Test Type: Capability.

Annex B
(informative)

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

There currently exist in the world 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 part of ISO 19144 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. For example 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 may derive directly from the classification system, or it may 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 part of ISO 19144 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.

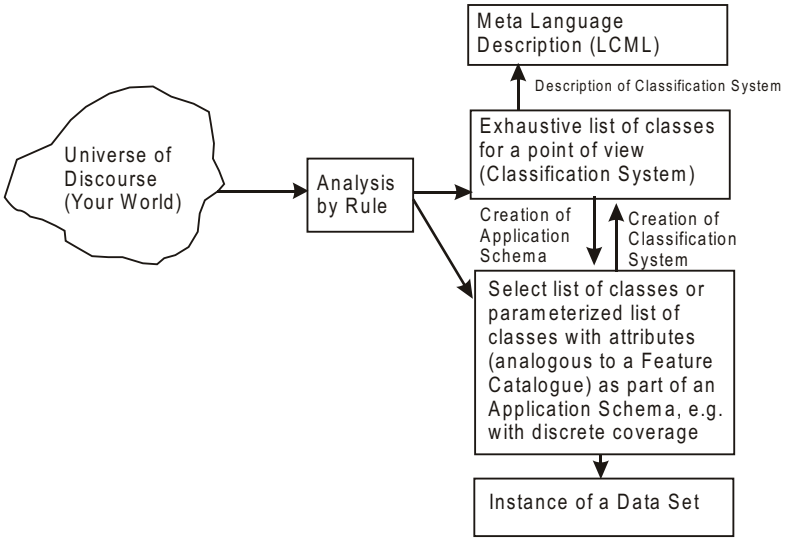


Figure B.1 — Logical Framework

The core of the LCML is the composition of an LC_LandCoverDescriptor 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 may be organized and how they relate to a discrete coverage. Examples are legends derived from the UNFAO LCCS, the USGS Anderson system, or the European Corine system.

At the third level are application schema used for a particular type or a series of data sets. Such an application schema needs to be compliant with the rules for Application Schema as described in ISO 19109. At the application schema level the classes of the classification scheme 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 may 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.

At the fourth level a specific set of data is an instance of the application schema.

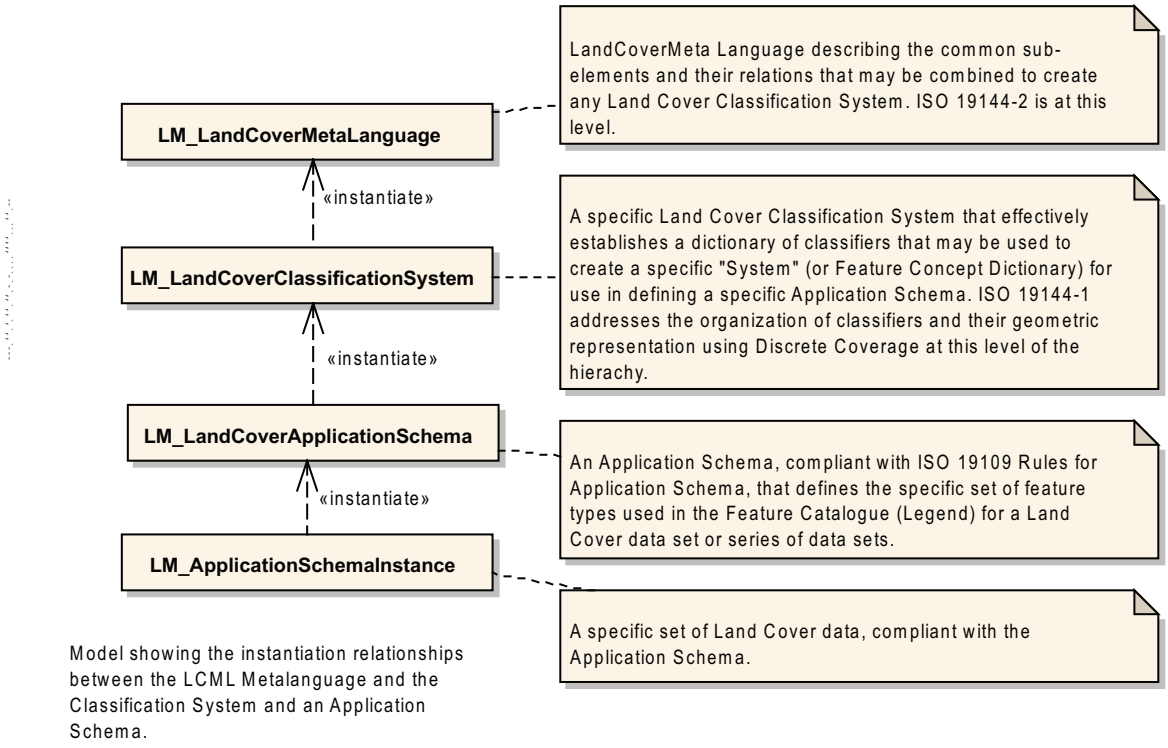


Figure B.2 — Levels of abstraction in the relationship of the LCML to an Application Schema

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 alalytical technique to establish an ontology. Classes with shared elements may be compared even though the name of the class in different classification systems may be different.

Annex C
(informative)

Examples

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.

The examples are of two types. The first set of examples C.2 to C.11 relate 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.

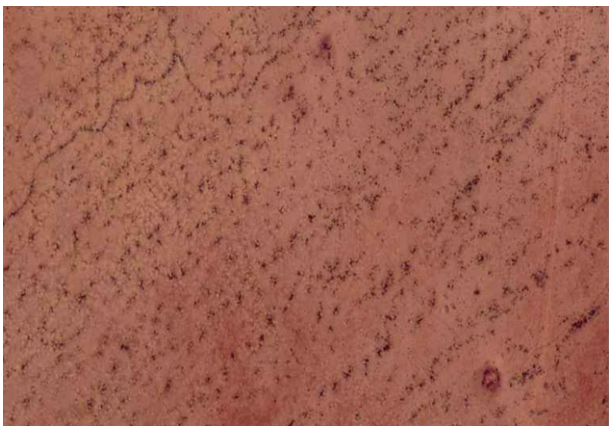
The second set of examples C.12 to C.16 are selected from some of the widely used land cover classification systems. This illustrates that these land cover classification systems can be represented using the LCML. Only a few classes have been shown although in some cases the complete representation of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

NOTE For the examples in this Annex the class names begin with the two letter code EL to distinguish them from any other classes in the ISO/TC 211 harmonized model and avoid any inadvertent clashes with names that may be generated in other standards. A detailed class by class 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 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 (on the left) and from a satellite image [Ikonos] (on the right). This may be treated as one land cover type with two horizontal patterns open shrub patches and open grassland in distinct patterns.

a) Oblique view



b) Satellite image

Figure C.1 — Example of Tiger Bush

The model illustrated in Figure C.2 shows a class EL_TigerBush composed of elements that correspond to instances of the metalanguage objects from LCML. The class EL_TigerBush could be a 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 class EL_TigerBush is an instance of LC_LandCoverClass and is composed of two separate instances of EL_TigerBush:LC_HorizontalPattern.

The first instance of EL_TigerBush:LC_HorizontalPattern has the attribute *patternType* = elongated, *patternCoveragePercentage* = the range 15,0; 25,0 %, and *patternOccurrence* = 100 %. This instance of EL_TigerBush:LC_HorizontalPattern is composed of EL_TigerBush: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_TigerBush: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_TigerBush:LC_Stratum (vegetation) is composed of EL_TigerBush: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_TigerBush:LC_Shrub is composed of EL_TigerBush:LC_NaturalOrSeminaturalVegetation which is a growth form characteristic further refining the class EL_TigerBush:LC_Shrub.

The second instance of EL_TigerBush:LC_HorizontalPattern has the attribute *patternCoveragePercentage* = the range 75,0; 85,0 %, and *patternOccurrence* = 100 %. This instance of EL_TigerBush:LC_HorizontalPattern is composed of EL_TigerBush:LC_Stratum which has the attribute *name* equals 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_TigerBush:LC_Stratum is composed of EL_TigerBush: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_TigerBush:LC_HerbaceousGrowthForm is composed of EL_TigerBush:LC_NaturalOrSeminaturalVegetation which is a growth form characteristic further refining the class EL_TigerBush:LC_HerbaceousGrowthForm. This is shown in Figure C.2.

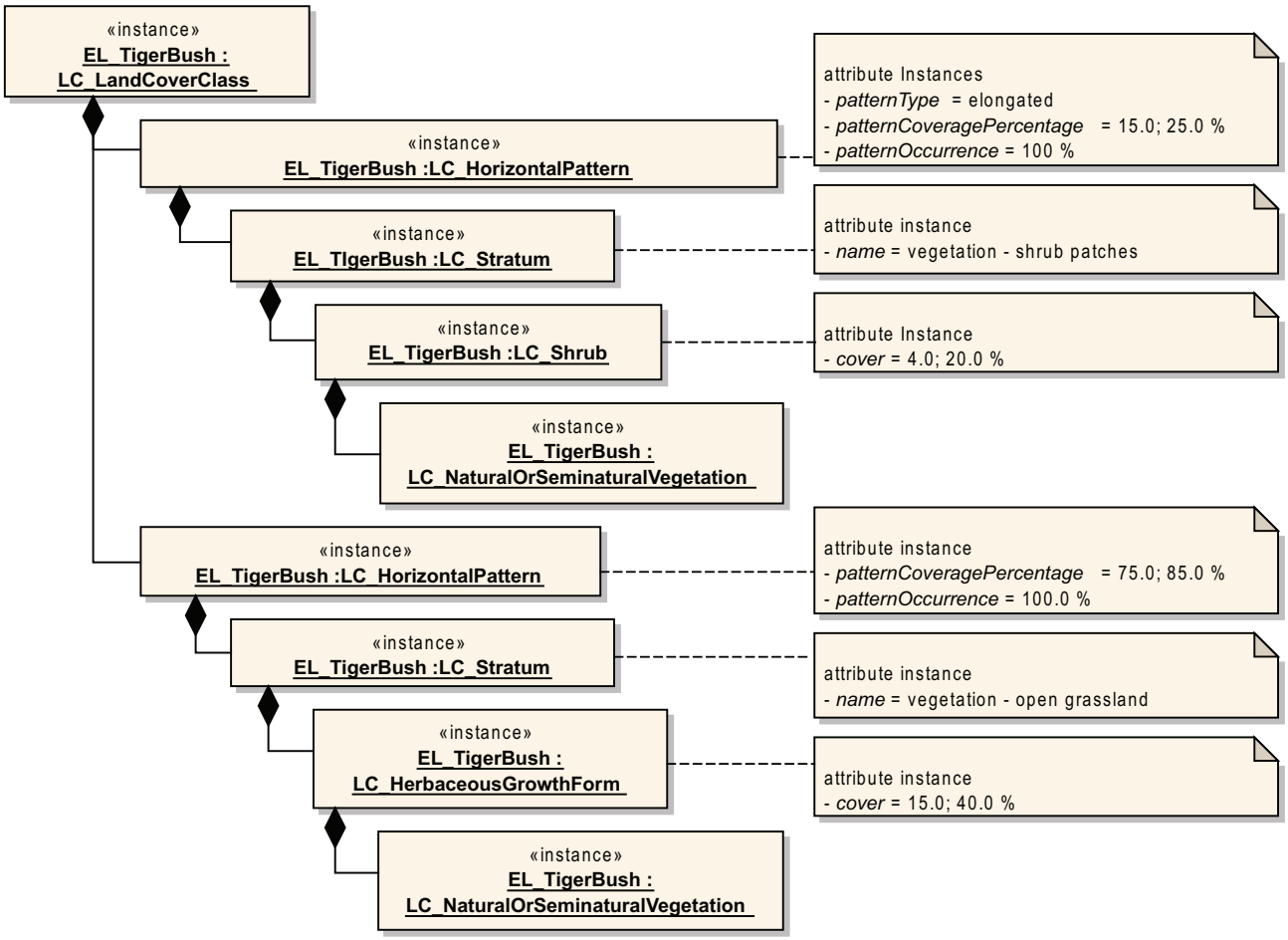


Figure C.2 — Example of Tiger Bush class element composition

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.3).

Figure C.3 — Example of a Tree and Shrub Savannah in three strata

The model illustrated in Figure C.4 shows a class EL_Savannah:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class 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 %).

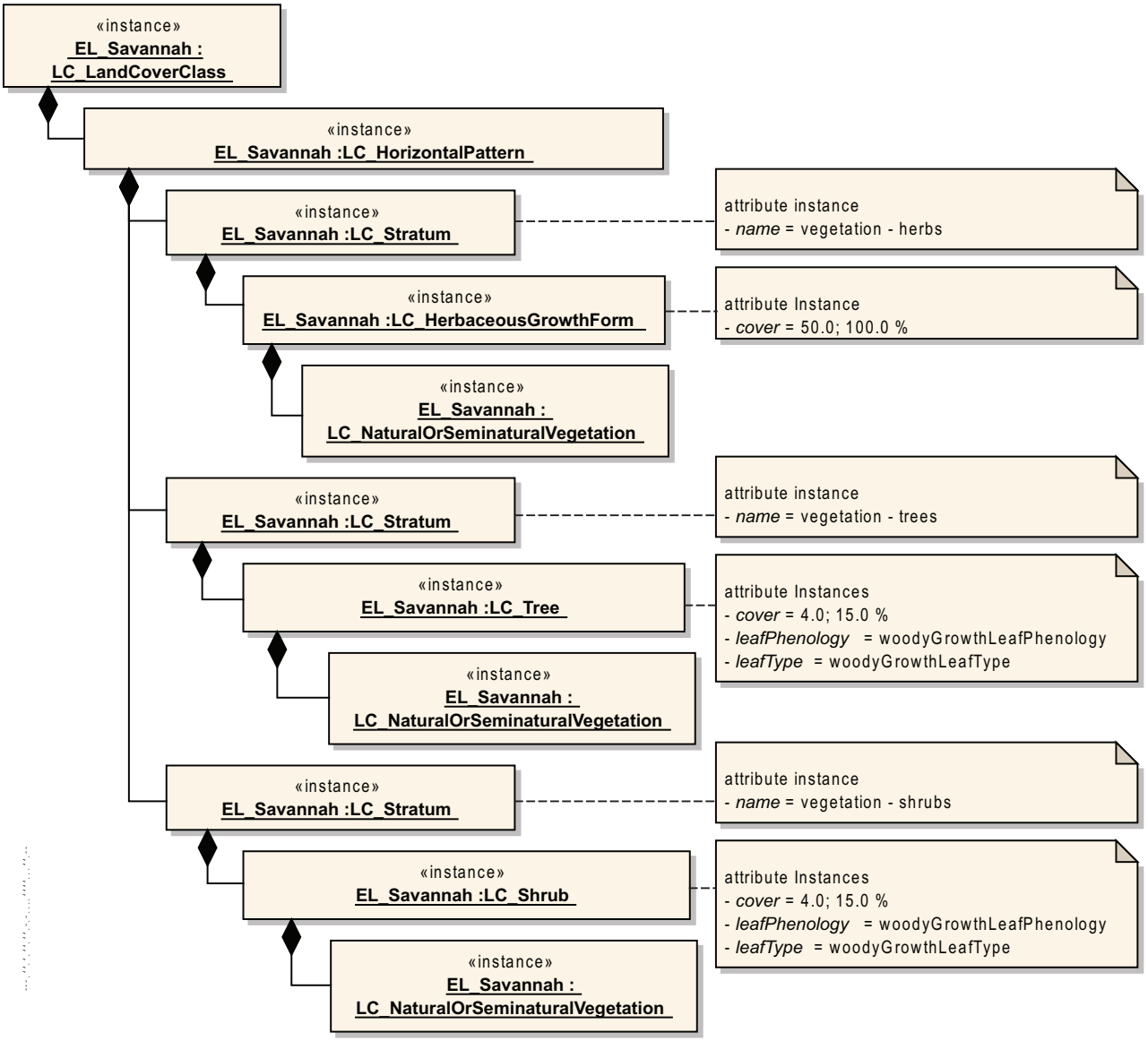


Figure C.4 — Example of a Tree and Shrub Savannah class element composition

C.4 Example 3 — Vegetation in one stratum — Herbs and Dwarf Shrubs

This example describes two vegetation elements within one stratum. Herbs compete for space with Dwarf Shrubs. The whole form a single stratum were the sum of the cover of both elements is not more than 100 %. See Figure C.5.

Figure C.5 — Example of Herbs and Dwarf Shrubs in one stratum

The model illustrated in Figure C.6 shows a class EL_DwarfShrubs:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class EL_DwarfShrubs:LC_

LandCoverClass has been built up with a layer of herbaceous growth with cover (70 to 90 %) and a layer of shrubs with open cover (10 to 30 %) and height (0,2 to 0,5 m).

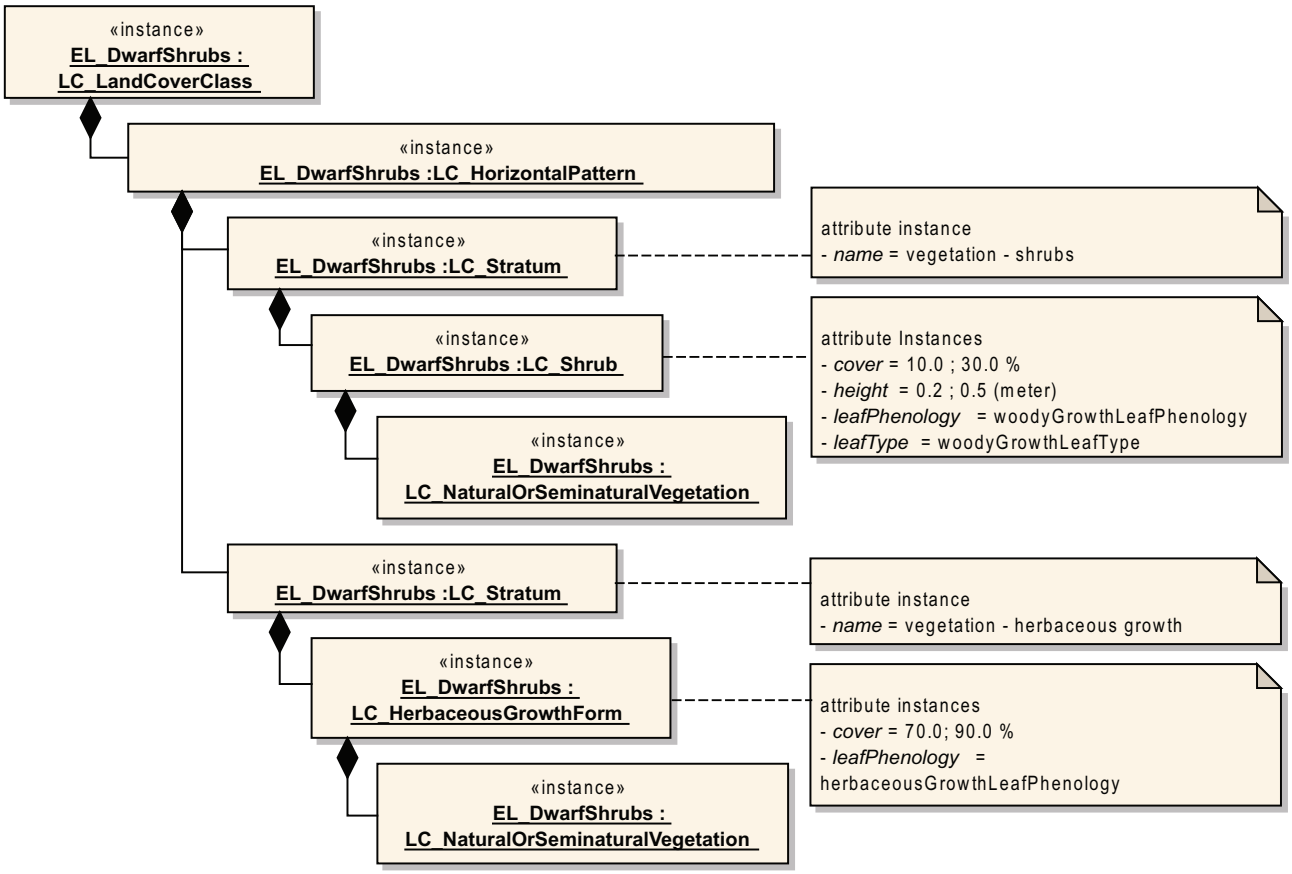


Figure C.6 — Example of Herbs and Dwarf Shrubs class element composition

C.5 Example 4 — Boulders with Moss in a Grassland

This example illustrates the “on Top” relationship. It describes boulders with moss on top of the boulders, in a grassland. Three stratums are defined. The first stratum contains the herbaceous growth form corresponding to grassland. The second contain boulders. The third contains moss and includes an “onTop” relation to the stratum before it, the stratum containing the boulders (see Figure C.7).

Figure C.7 — Example of Boulders with Moss in a Grassland

The model illustrated in Figure C.8 shows a class EL_BouldersWithMoss:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class 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 The relationship interStrataRelationship (see 8.6.2.4) is navigable in only one direction and is 1 to 0..1 (one to one optional). This means that the association class may be implemented as an attribute on the instantiated class. This is what is shown in these examples.

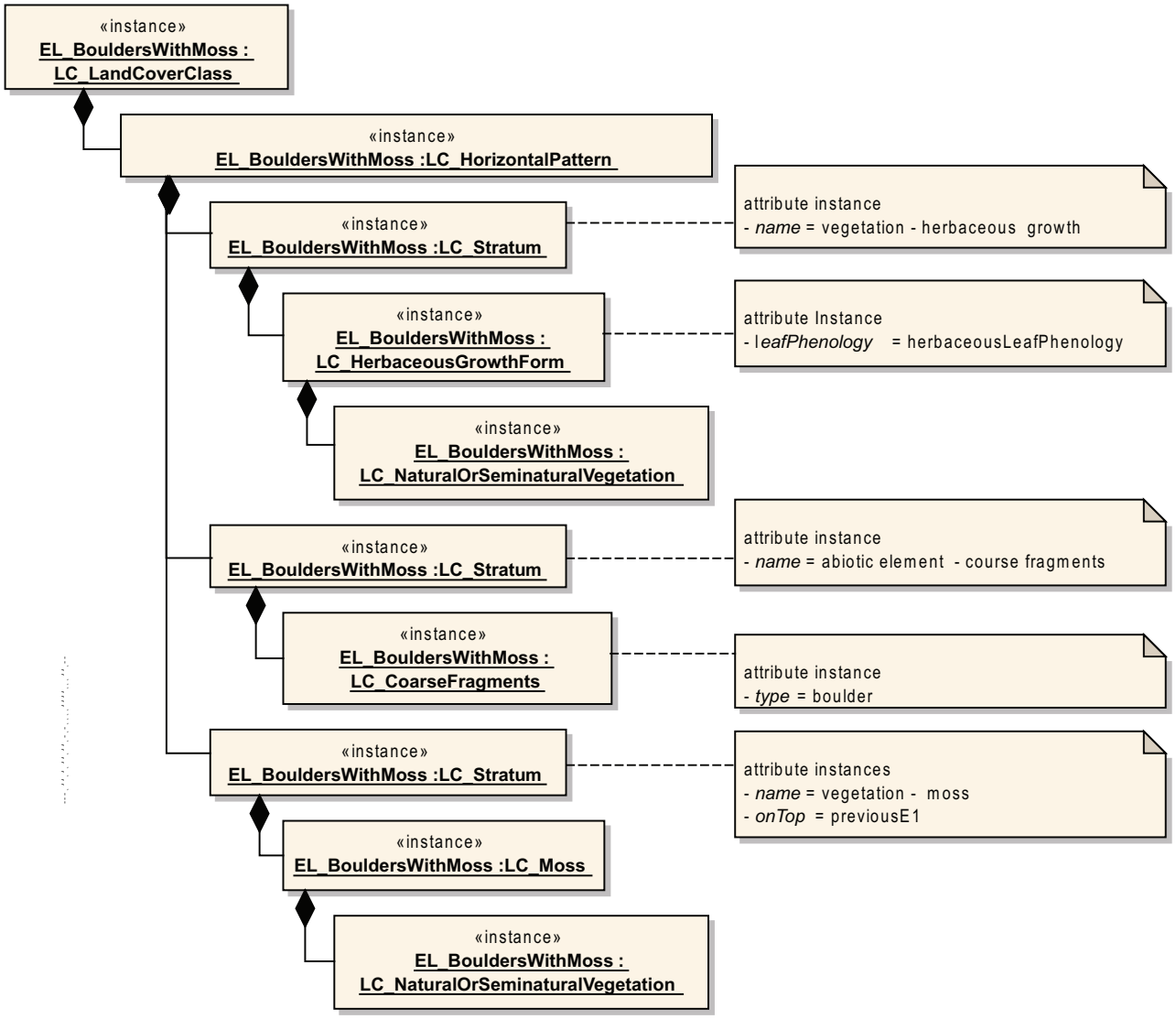


Figure C.8 — Example of Boulders with Moss in a Grassland class element composition

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.9).

Figure C.9 — Example of a Mangrove Swamp in two strata

The model illustrated in Figure C.10 shows a class EL_Mangrove:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class EL_Mangrove:LC_LandCoverClass has been built up with a layer of trees and a water body layer.

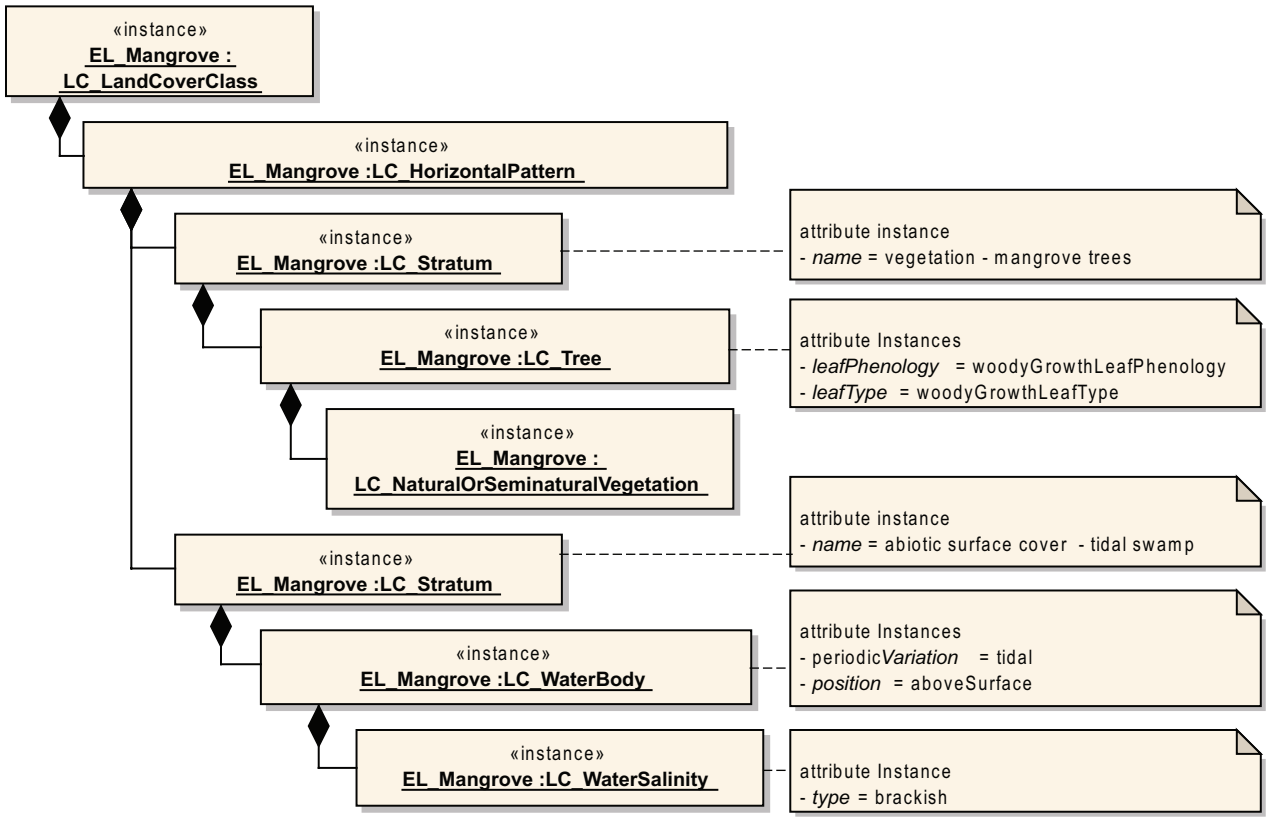


Figure C.10 — Example of a Mangrove Swamp class element composition

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.

The model illustrated in Figure C.11 shows a class EL_BuildingWithRoofGarden:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class 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 and fourth layer are of trees. Each of these are also on top of the building. For simplicity no attributes have been defined to characterize the elements in this example.

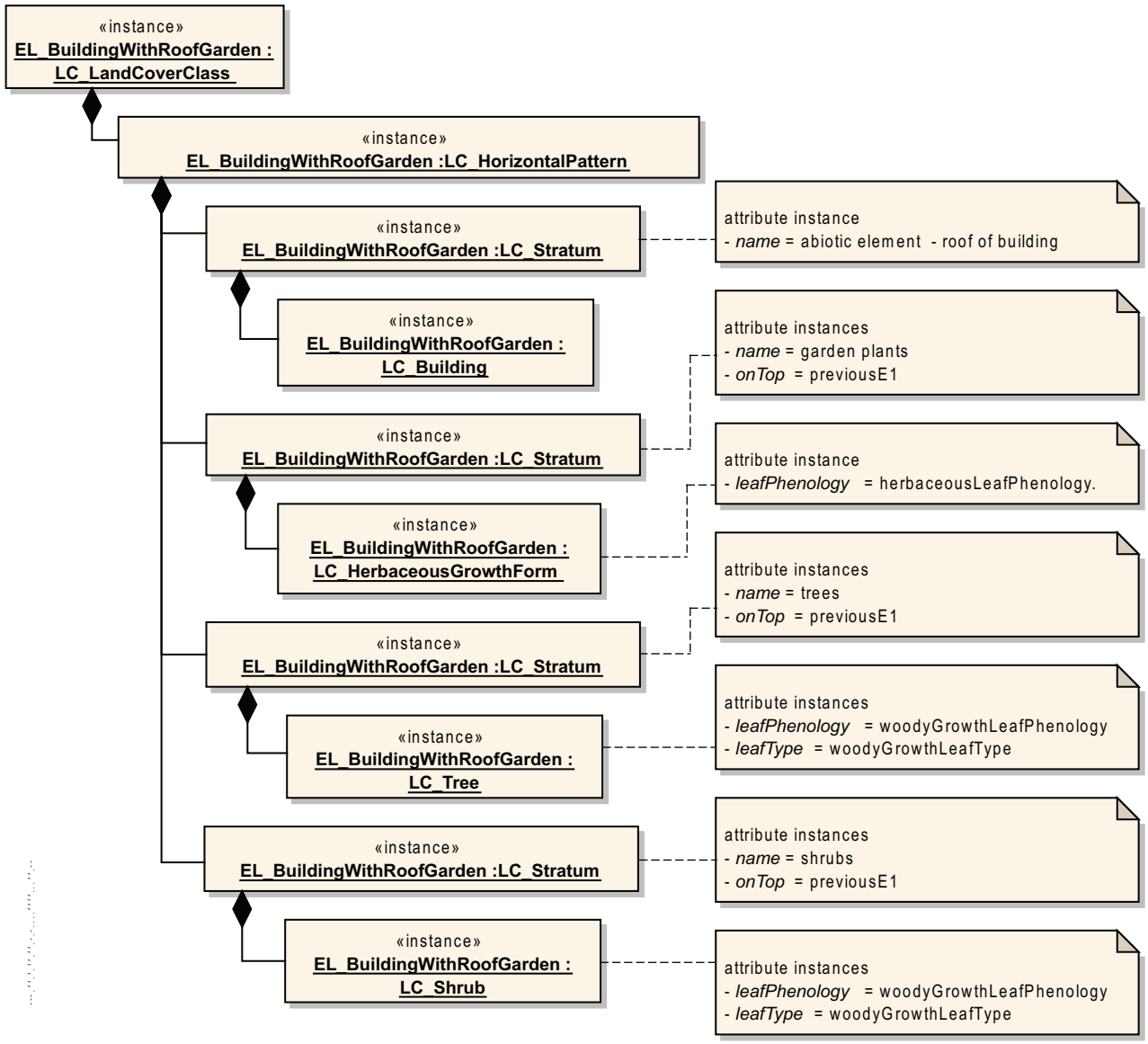


Figure C.11 — Example of Building with Roof Garden class element composition

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, 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.

The model illustrated in Figure C.12 shows a class EL_BorealAndHemiborealForest:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class 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.

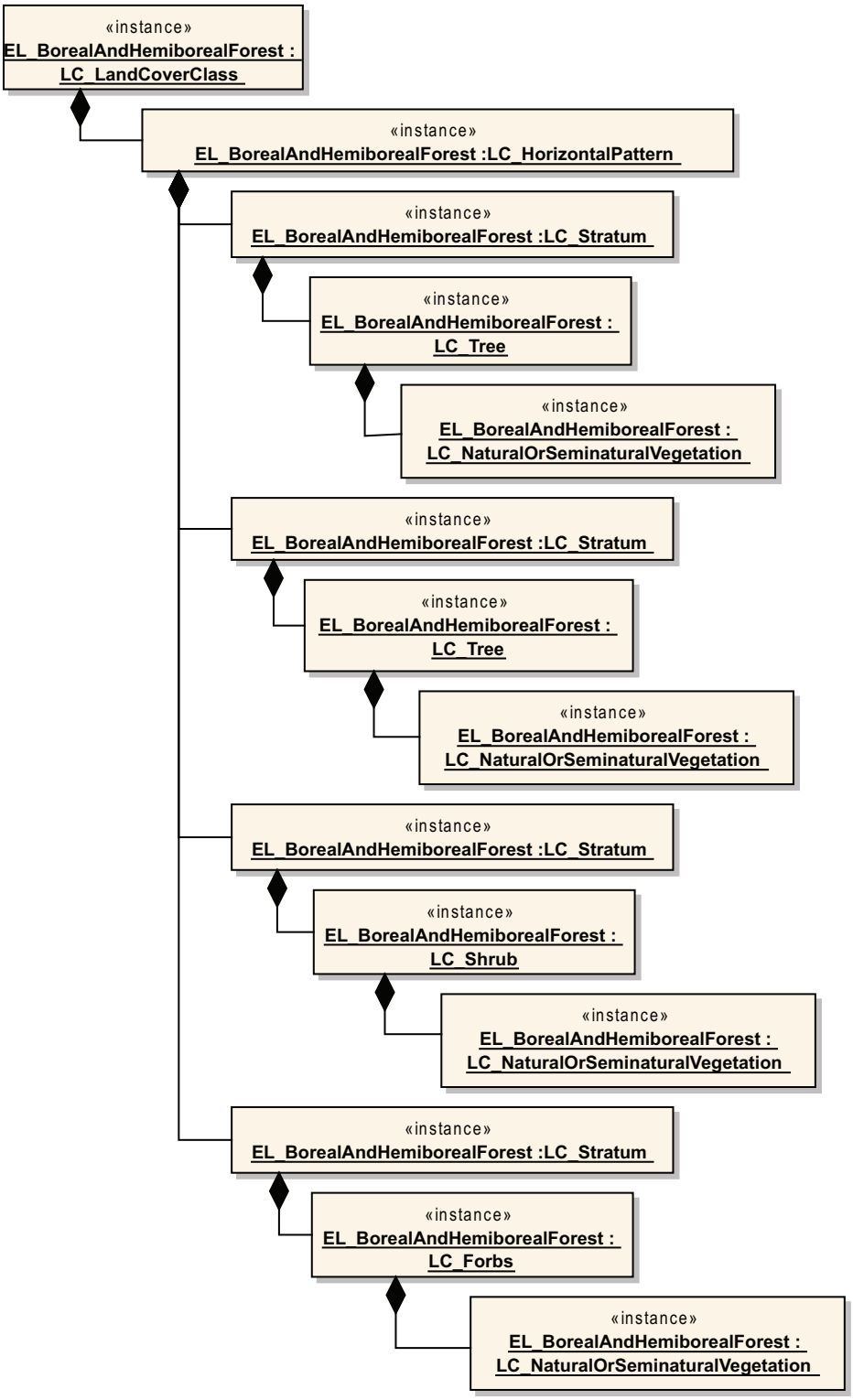


Figure C.12 — Example of a Boreal and Hemi-boreal Forest in four strata class element composition

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 is 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 has an appearance looking like a kind of park landscape (see Figure C.13).

NOTE Photo: © Yngve Rekdal, Norwegian Forest and Landscape Institute, used with permission.

Figure C.13 — Example of a Hagemarklandscape

The model illustrated in Figure C.14 shows a class EL_Hagemarklandscape:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class 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 %).

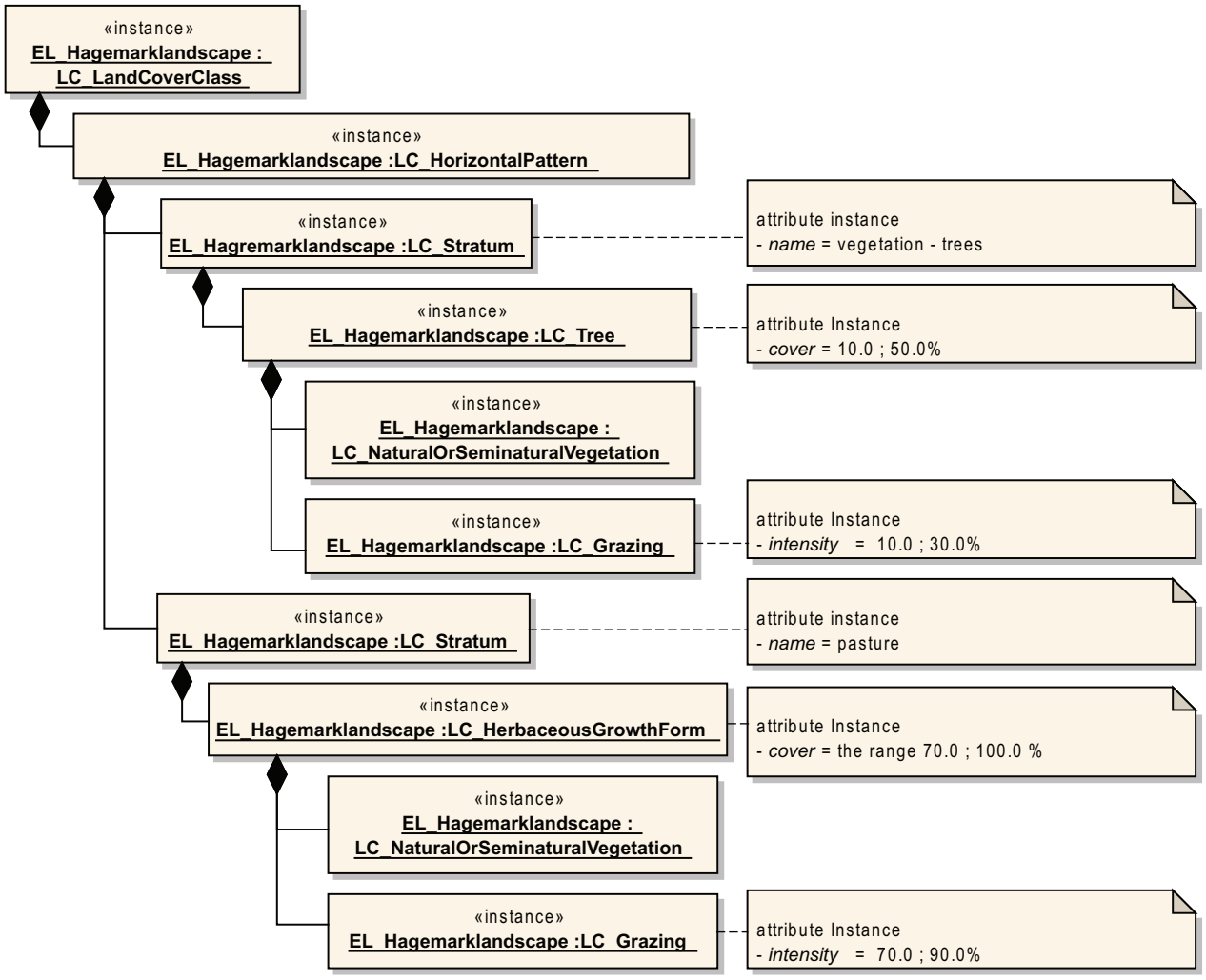


Figure C.14 — Example of a Hagemarklandscape class element composition

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 Graminae vegetation that is characterized as Cultivated and Managed Vegetation with a Floristic Aspect Species “Wheat”.

The model illustrated in Figure C.15 shows a class EL_BareFieldsPlantedWithWheat:LC_LandCoverClass composed of elements that correspond to instances of the metalanguage objects from LCML. The class EL_BareFieldsPlantedWithWheat:LC_LandCoverClass has been built up with one Stratum that has two elements EL_BareSoil and EL_Graminae. The metalanguage instance EL_Graminae is characterized by EL_CultivatedAndManagedVegetation and by EL_FloristicAspect with EL_FloristicAspectSpecis (Wheat).

NOTE The relationship interStrataRelationship (see 8.6.2.6) is navigable in only one direction and is 1 to 0..1 (one to one optional). This means that the association class may be implemented as an attribute on the instantiated class. This is what is shown in these examples.

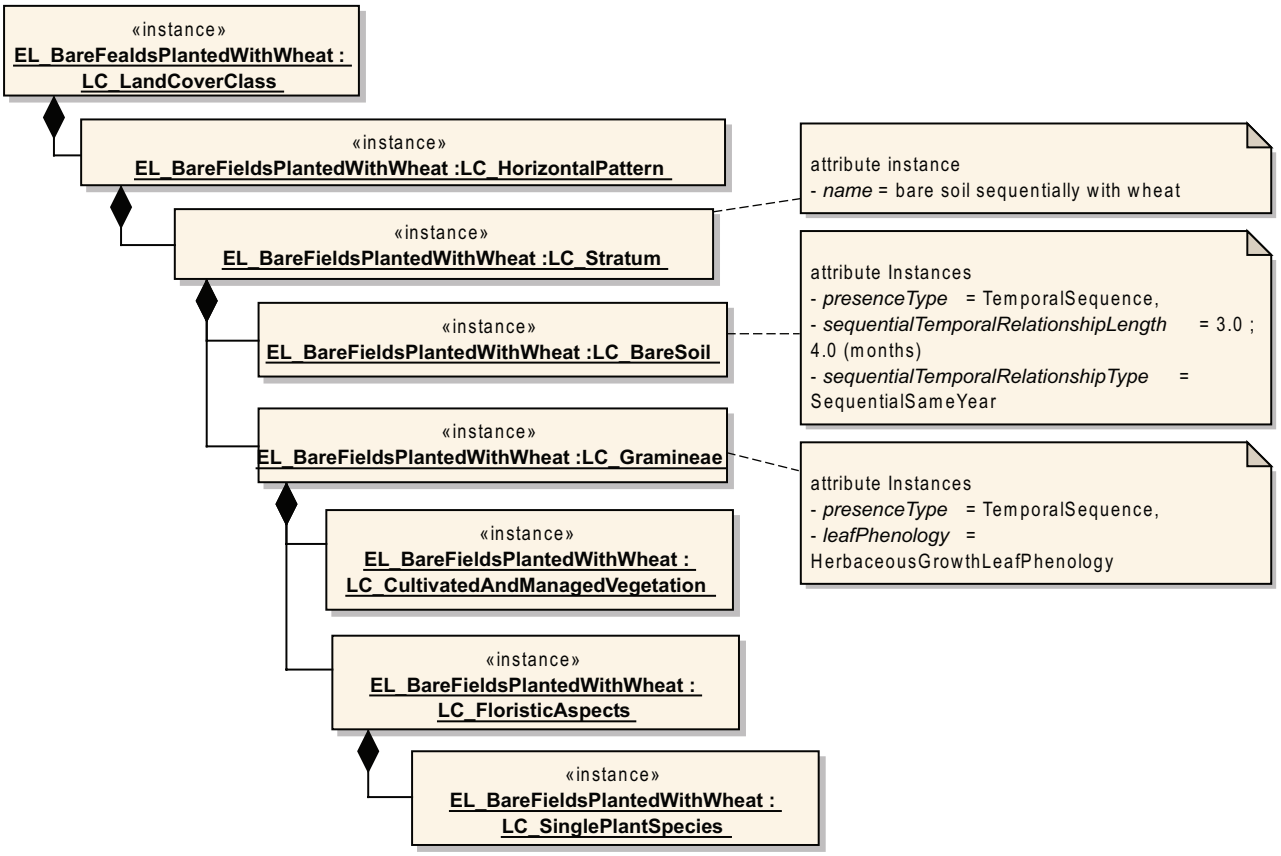


Figure C.15 — Example of a Bare Field planted with Wheat Same Year class element composition

C.11 Example 10 — Greenhouse

This example shows an area which is covered by a greenhouse building. The LCML does not explicitly include an attribute for identifying a building as being of type “greenhouse”. The attribute type and the attribute value greenhouse are added by the user of the LCML as part of the specific land cover classification system being used. This attribute and attribute value may be added as a one time instance or recorded in a register so that it can be reused within the land cover classification system described using the LCML.

The model illustrated in Figure C.16 shows that one layer is used; composed by the LCML element Building. The LCML element Building has three properties: Construction Material (Light Material), Cover (from 80 to 100 %) and Height (from 4,0 to 8,0 m).

The metalanguage instance EL_Building is characterized by EL_Use. The LCML metalanguage object LC_Use allows the user to establish different ways of describing use and allows attributes to be established through registration. In this example the attribute type and the attribute value greenhouse are established.

Note that the extension of the LCML through the addition of attributes and attribute values allows for any land cover construct to be described; however, if an extension is used in the description the extension may not map to a different land cover classification system that does not support through registration the same extension. That is, if a second land cover classification system does not support the concept of “greenhouse” the information would translate to an undefined building type, which is the best semantic match which could be achieved.

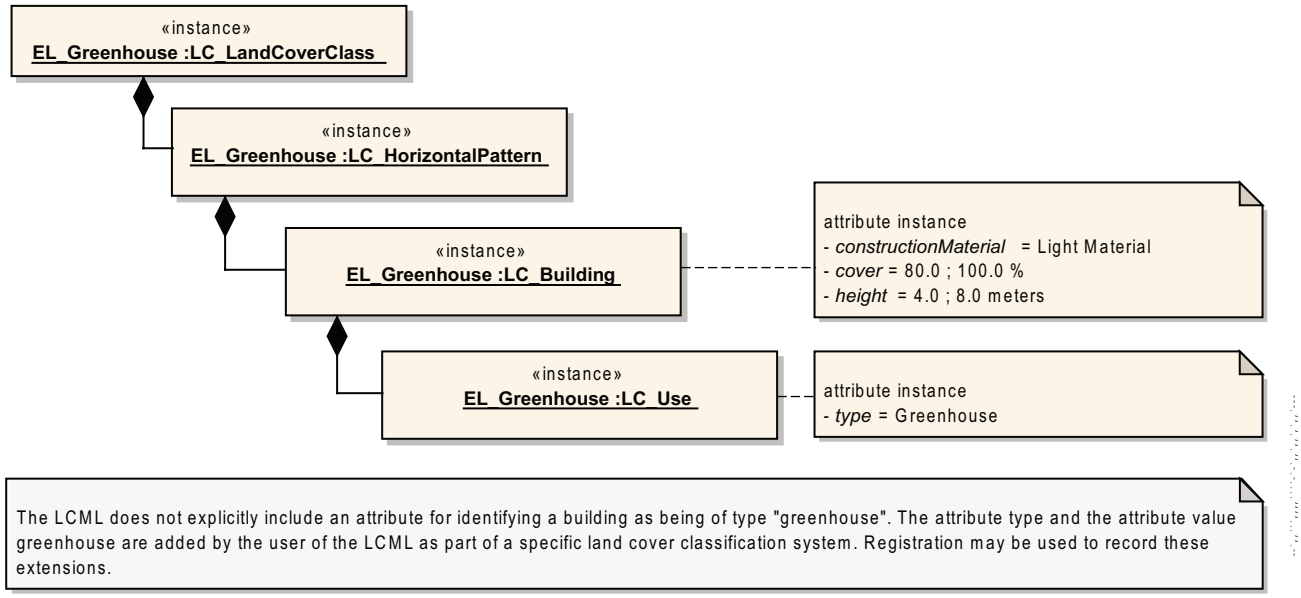


Figure C.16 — Example of Greenhouse (with a user defined attribute and value)

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

This example is a translation of a class from the CORINE land cover classification system. The CORINE description is “vegetation formation composed principally of trees (cover more than 30%), including shrub and bush under storeys, where broad-leaved species predominate”.

The model illustrated in Figure C.17 shows that two layers are used. The first one 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 (“Conditional”).

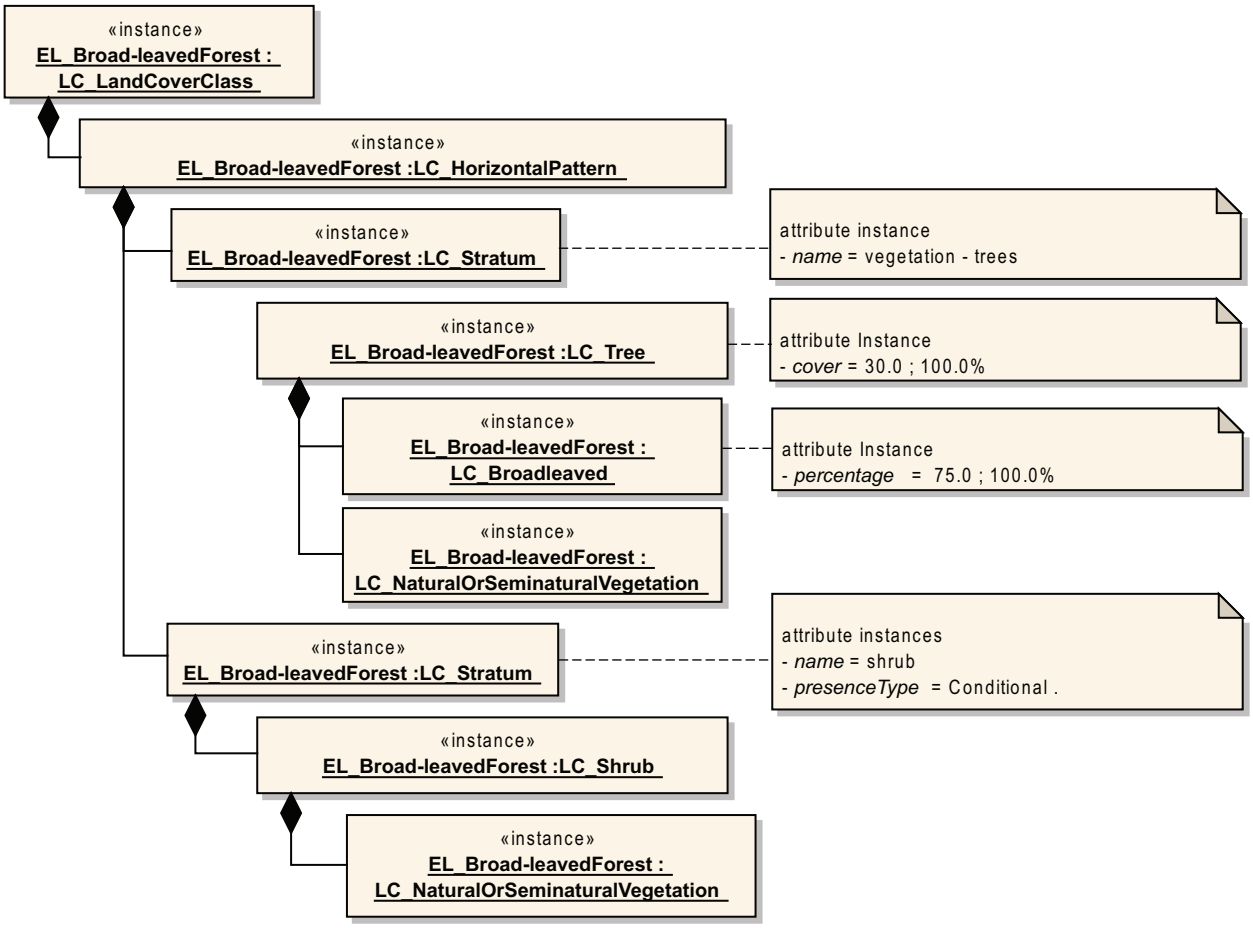


Figure C.17 — Example of CORINE Broad-leaved Forest class element composition

C.13 Example 12 — Example CORINE class 111 Continuous Urban Area (s)

This example is a translation of a class from the CORINE land cover classification system. The CORINE description is “most of the land is covered by structures and the transport network. Building, roads and artificially surfaced areas cover more than 80% of the total surface”.

The model illustrated in Figure C.18 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.

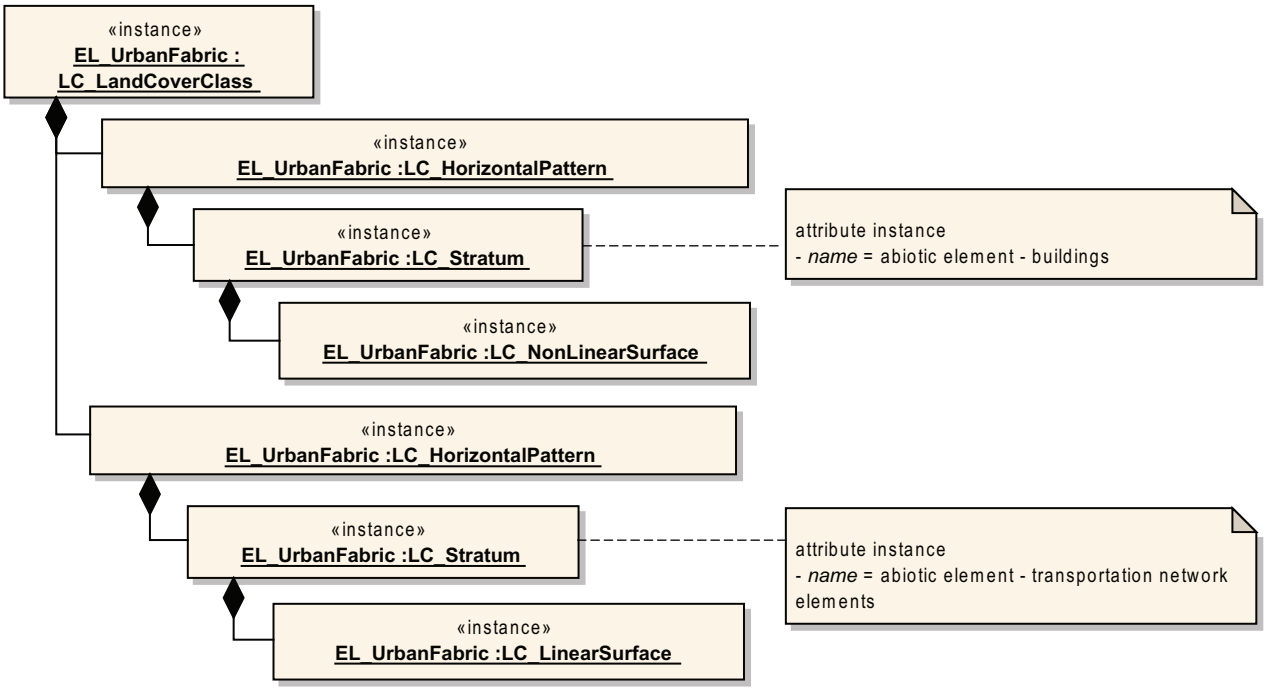


Figure C.18 — Example of CORINE Continuous Urban Area class element composition

C.14 Example 13 — Example CORINE class 244 Agro-Forestry Area (s)

This example is a translation of a class from the CORINE land cover classification system. The CORINE description is “annual crops or grazing land under the wooded cover of forest species”.

The model illustrated in Figure C.19 shows that two layers are used. The first one 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 Grazing which comes from LC_GrowthFormCharacteristic). The second one 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 to specify the property Cover.

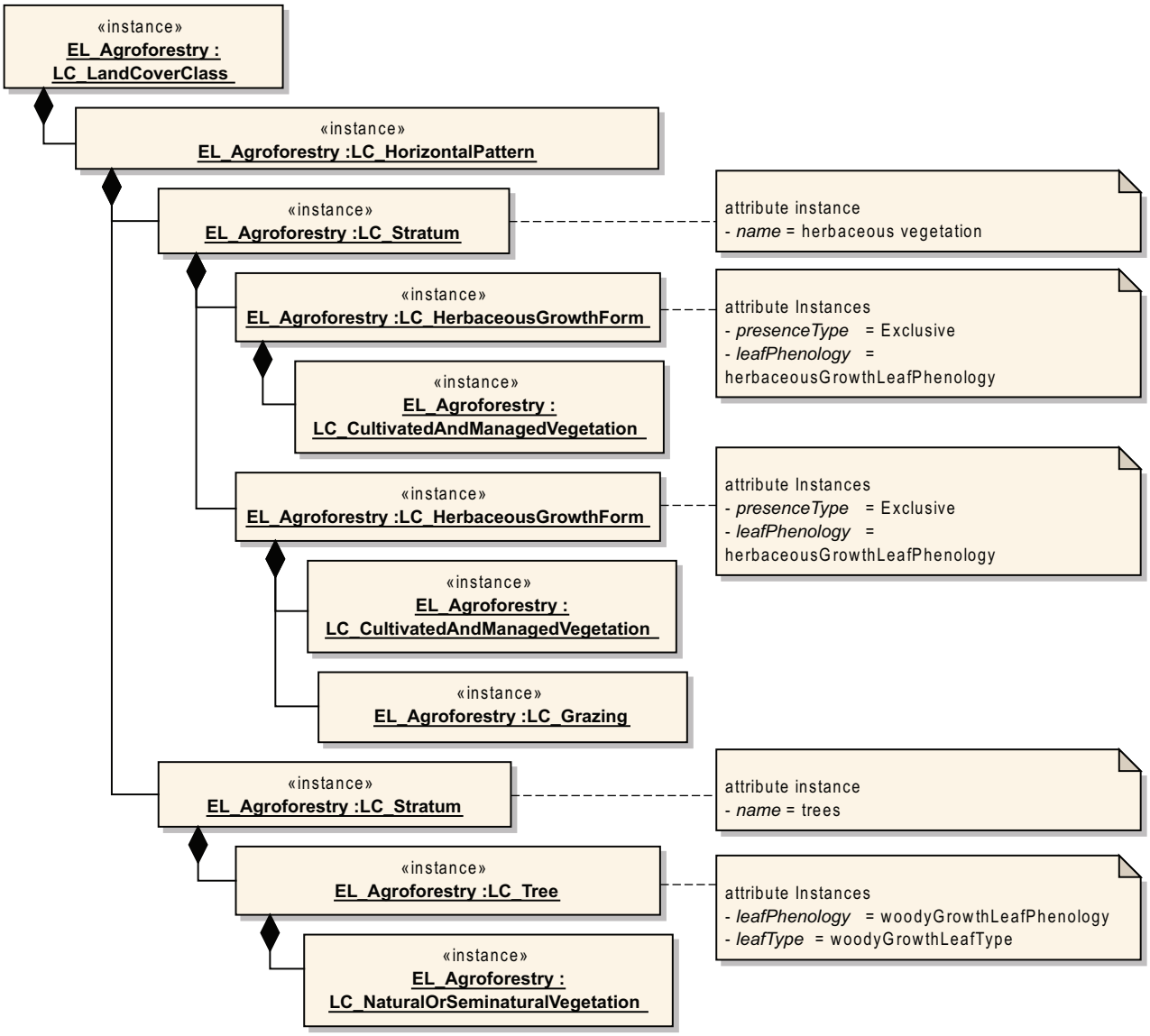


Figure C.19 — Example of CORINE Agro-Forestry Area class element composition

C.15 Example 14 — Example Evergreen Forest Land (Anderson)

This example is a translation of a 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”.

The model illustrated in Figure C.20 shows that one layer is used composed by the LCML element Tree (with an extra characteristic Natural) is used. The LCML element Tree has two properties: Cover (from 30 to 100 %) and Evergreen.

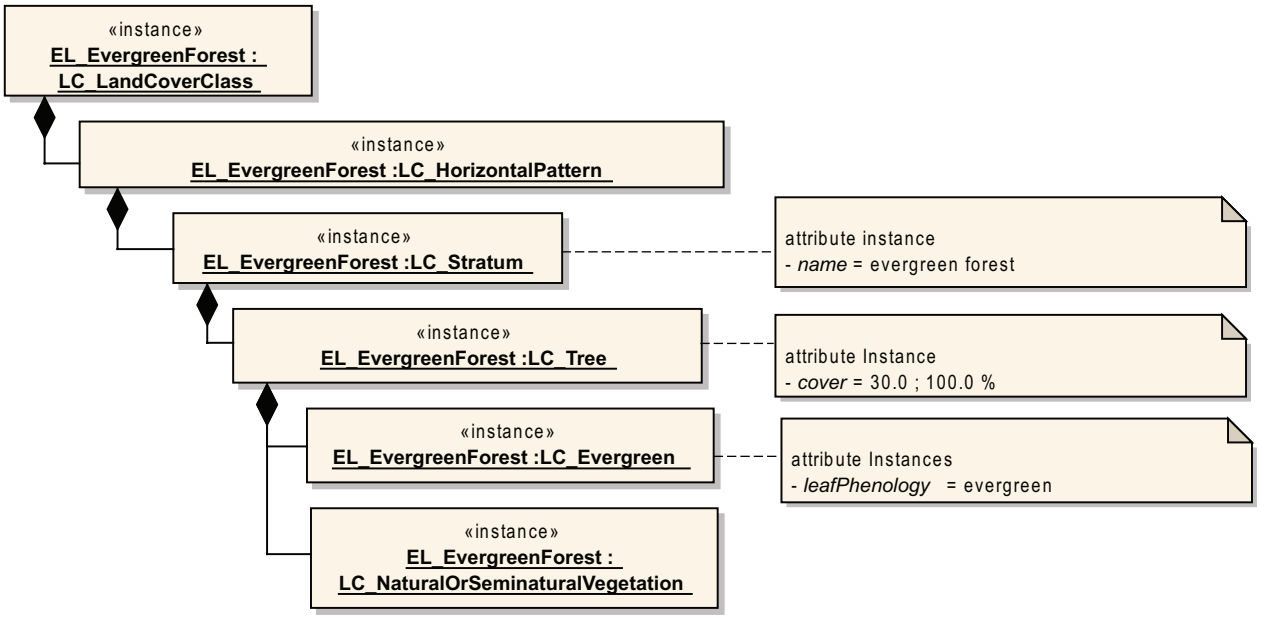


Figure C.20 — Example of Evergreen Forest Land (Anderson) class element composition

C.16 Example 15 — Example Herbaceous with Sparse Tree/Shrub (Global Map)

This example is a translation of a class from the Global Map[5)] land cover classification system. Global Map has adopted the UNFAO LCCS standard. The definition of the class is the following: “the main layer consist of herbaceous vegetation from closed to open, the second and third layers are composed by sparse trees and sparse shrubs”.

The model illustrated in Figure C.21 shows that three separate layers are used. The first one composed by 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 %).

5) 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.

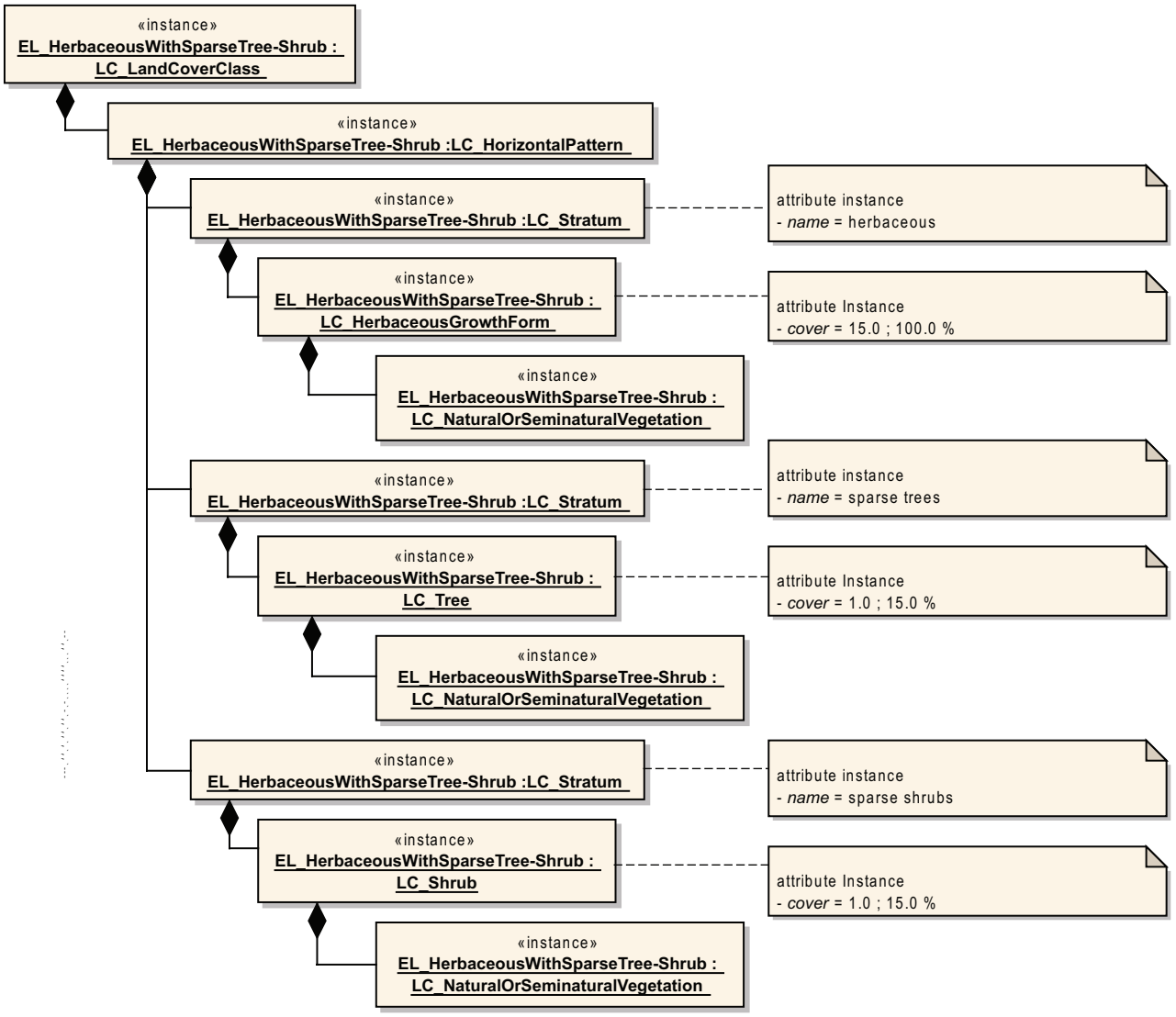


Figure C.21 — Example of Herbaceous with Sparse Tree/Shrub (Global Map) class element composition

Annex D
(informative)

Glossary of land cover meta-elements

D.1 Glossary introduction

This glossary contains a set of definitions that may 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 ease reference 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 may be the set defined in this glossary, or it may be another defined nationally or by an organization. However, where terms differ a comparison using the LCML will generate different results. For example, if there is disagreement between two glossaries on the definition of a tree, then the LCML might 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 done 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 part of ISO 19144. The definitions in this annex are given as one reference glossary.

In order to make reference easier an alphabetical index is also provided.

D.2 Vegetation

D.2.1 Growth Forms

A Growth Form is a group of plants having certain morphological features in common (Kuechler and Zonneveld, 1988). 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 expressed as a percentage of area covered by the growth form. It is a proportion of the ground, substrate or water surface covered by a layer of plants, considered at the greatest horizontal perimeter level of each plant in the layer.[11]

D.2.4 Growth Form types

A distinction can be made between the different plant growth forms on basis of their physiognomic aspects. Woody plants (sub-divided into Trees, Shrubs and Woody) are distinguished from Herbaceous (which are sub-divided into Forbs and Graminoids), Lichens/Mosses and Algae *Growth Forms*. 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.[28] [20]

D.2.5 Woody

Perennial plants with stem(s) and branches from which buds and shoots develop are defined as woody.[15] Semi-woody plants are included here.[11] Depending on the branching symmetry, a distinction is made between Trees and Shrubs.[28] With reference to the International Classification and Mapping of Vegetation,[32] bamboos and tuft plants (palms, tree ferns, etc.) can also belong to this category. Depending on their height, they are classified as Trees or Shrubs.

D.2.6 Trees

A tree is defined as a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown.[15]

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.2.7 Shrubs

Shrubs are woody perennial plants with persistent woody stems and without any defined main stem, being less than 5 m tall.[15] 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.2.8 Leaf Phenology properties for Woody Growth Forms

D.2.8.1 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.2.8.2 Evergreen

This term describes the phenology of perennial woody plants that are never entirely without green foliage.[15]

D.2.8.3 Deciduous

This applies to the phenology of perennial woody plants that are leafless for a certain period during the year.[15] The leaf shedding usually takes place simultaneously in connection with the unfavourable season.[32]

D.2.9 Leaf Type properties for Woody Growth Forms

D.2.9.1 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.2.9.2 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.2.9.3 Needleleaf

This refers to trees and shrubs of the botanical group *Gymnospermae*,[15] 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.2.9.4 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.[20]

D.2.9.5 Broadleaf properties

The properties of broadleaf leaves can be further characterized by leaf “Arrangement” on the stem, leaf “Shape” and leaf “Venations”, as described by Ghillean Tolmie Prance.[17]

D.2.10 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 may or may not be decussate.

D.2.11 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 (it would be pinnate then)
— 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.2.12 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.

— parallel (linear leaf): Parallel-veined, parallel-ribbed, parallel-nerved, penniparallel – veins run parallel for the length of the leaf, from the base to the apex. Commissural veins (small veins) connect the major parallel veins. Typical for most monocotyledons, such as grasses.

D.2.13 Herbaceous

D.2.13.1 Herbaceous general

Plants without persistent stem or shoots above ground and lacking definite firm structure are defined as herbaceous.[26] There are two categories, depending on the physiognomy, namely *Graminoids* and *Forbs*.[20]

D.2.13.2 Herbaceous leaf phenology properties

The following properties can be applied to the herbaceous layer:

— **Annual**: annual plants usually germinates, flowers and dies in one year. However, if prevented from seeding annuals can live longer than a year. Some seedless plants can also be considered annuals even though they do not flower.

— **Biennial**: A biennial plant is a flowering plant that takes two years to complete its lifecycle. In the first year the plant grows leaves, stems, and roots (vegetative structures), in the colder months the plant becomes dormant and in the spring the plant then flowers, producing fruits and seeds before it finally dies.

— **Perennial**: A perennial plant lives for more than two years. When used as a noun, this term applies specifically to herbaceous plants, even though woody plants like shrubs and trees are also perennial in their habit.

D.2.14 Forbs

D.2.14.1 Forbs general

Forbs are all broad-leaved herbaceous flowering plants that are not graminoids (e.g. sunflower, clover, etc.[32]). Therefore ferns, except tree ferns,[20] and very low non-leafy succulents are included.[11] The term is often used to describe broadly similar growth forms.

D.2.14.2 Forbs status

Forbs can be further classified as:

Rooted: plants that have a root system related to a subsoil substratum

Not Rooted: a non-anchored plant that floats freely in the water or on the water surface, e.g. formations like common duckweed (Lemna minor) or water hyacinth (Eichhornia crassipes).[32] [8]

D.2.15 Graminoids

All herbaceous grasses and other narrow-leaved grass-like plants that are not grasses according to the taxonomic definition.[20] Bamboos are technically grasses but they are Woody in form and therefore classed with Shrubs or Trees.

D.2.16 Lichens/Mosses

D.2.16.1 Lichens

Lichens are composite organisms formed by the symbiotic association of fungi and algae. They are found encrusting rocks, tree trunks, etc. and they are often found under extreme environmental conditions.[21] In tundras of North America and Eurasia, lichens (e.g. Cladonia spp.) may cover large areas.[20]

D.2.16.2 Mosses

Mosses are a group of photo-autotrophic land plants without true leaves, stems or roots, but with leaf- and stemlike organs, e.g. sphagnum.[16] Several plants commonly called “mosses” in fact belong to other groups: reindeer moss is a lichen; Spanish moss is a vascular plant (parasite) and Irish moss is an alga.[21]

D.2.17 Algae (sing. alga)

Algae are a large and diverse group of typically eukaryotic organisms, ranging from unicellular to multicellular forms. The largest and most complex marine forms are called seaweeds. The main difference from plants is that they have cholophyll as the primary photosynthetic pigment, they do not have a true vascular system and there is no sterile layer of cells surrounding the reproductive cells. There are 3 main types of macrophytic algae: red (Rhodophyceae), brown (Phaeophyta) and several groups of green algae.[2] Macrophytic algae are big enough, to be easily seen without a lens or a microscope.

NOTE The prokaryotic cyanobacteria (commonly referred to as blue-green algae) are no longer considered true algae.[2]

Algae can be further subdivided using the following properties:

— **Floating**: motile suspended in the water.

— **Submerged**: non motile, attached to a surface through a film (mucus), filaments or specialized structures such as holdfast (such as the marine seaweeds).

D.3 Characteristics for Growth Forms

D.3.1 Characteristics general

The Characteristics listed in D.3.2 to D.3.9 can be used to further describe the Growth Form layers.

D.3.2 Floristic aspect type

This category has two major divisions based on whether the floristic name is derived from a single plant species or from a group of plants. In the first case, a further sub-division is possible into *Dominant Species* (Height, Cover or combination of both) or *Most Frequent Species*. The second sub-division is sub-divided again into *Plant Groups* (e.g. Braun-Blanquet) and *Plant Groups Derived Without Statistical Methods* (i.e. same

ecological significance, same geographical distribution, same dynamic significance, etc.). The specific name of the *Floristic Aspect* can be added.

— List of species names to be added by user

— Single Plant Species: the user states the dominant or most frequent specie in the layer.

— Group of plant species types:

+statistically_derived_plant_group

+non_statistically_derived_plant_group

The floristic aspect is normally related to a single element. In the case when the floristic name is given by a plant group method, where several strata are involved then the same name is to be repeated for each of the strata.

D.3.3 Allometric measurements

The LCML system allows the user to add a number of measurement characteristics to the Growth Forms Layer, these are:

— **trunk diameter**: trunk diameter at breast height (DBH) is the stem diameter, including the bark, at 1,3m (4,5ft) above ground. Measurements are usually made with diameter tape, tree calliper or Biltmore stick. [4] The average tree diameter is the average diameter of the trees growing in a particular area (usually calculated per hectare).

— **crown diameter**: The diameter of tree crowns can be difficult to measure because they are often irregular and interlocked with branches of neighbouring trees. However, this is achieved by calculating an average diameter and then assuming a circular shape. A number of methods can be used to calculate the average diameter of the crown.[4] Within the system the measurement is stated in metres.

D.3.4 Growth form age

Growth form age is the age of a specific vegetative layer which is specified in months/years. The user can also specify if there is an “Even age” within the Growth Form strata or an “Uneven age”. For the “Uneven age”, it is the percentage of each group of plants having the same age.

D.3.5 Burnt status

The Burnt Status quality specifies the percentage of the total plants in a layer which have been affected by fire to an extent that they are no longer able to regenerate.

D.3.6 Dead status

The Dead Status quality specifies the percentage of the Growth Form in a specific layer which has died. Dead material can be identified by absence of foliage and bark and other signs of tissue degradation, such as lack of living tissue under the bark layer.

D.3.7 Water stress

When the soil is wet, the water has a high potential energy, is relatively free to move and is easily taken up by the plant roots. In dry soils, the water has a low potential energy and is strongly bound by capillary and absorptive forces to the soil matrix, and is less easily extracted by the crop. When the potential energy of the soil water drops below a threshold value, the crop is said to be water stressed. The effects of soil water stress are described by multiplying the basal crop coefficient by the water stress coefficient. LCML allows the user to state the percentage of plants which are water stressed.

D.3.8 Growth form illness

Pests (including mammals, slugs, insects, mites and nematodes) and diseases causes by fungi, bacteria and viruses can cause considerable damage to plants and is a major concern especially in agricultural and forestry

production systems.[1] The user can use the Growth form illness quality to specify the percentage of plants affected in a layer by a particular illness. The percentage is calculated by % of plants affected over the total of the strata. In addition the user can specify the type or organism causing the illness.

D.3.9 Grazing

Grazed areas are any type of vegetation regularly eaten by animals. The user can further define the intensity of grazing and the type of animal grazing. When grazing is applied to cultivated and managed vegetation, the vegetation can be grazed in the field or harvested and used as fodder for animals.

D.4 Natural and semi-natural vegetation

Natural vegetated areas are defined as areas where the vegetative cover is in balance with abiotic and biotic forces of its biotope. *Semi-natural vegetation* is defined as vegetation not planted by humans but influenced by human actions. These may result from grazing, possibly overgrazing the natural phytocenoses, or else from practices such as selective logging in a natural forest whereby the floristic composition has been changed, also previously cultivated areas which have been abandoned and where vegetation is regenerating are included. The human disturbance may be deliberate or inadvertent. *Semi-natural vegetation* includes thus, vegetation due to human influences but which has recovered to such an extent that species composition and environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. The vegetative cover is not artificial and it does not require human activities to be maintained over the long term.

D.5 Cultivated and managed vegetation

D.5.1 Cultivated and managed vegetation general

Cultivated and Managed Vegetation are areas where the natural vegetation has been removed or modified and replaced by different types of vegetative cover resulting from anthropic activities. This vegetation is artificial and requires human activities to be maintained over the long term. In between the human activities, the surface can be temporarily without vegetative cover. Its seasonal phenological appearance can be regularly modified by humans (e.g. irrigation). All vegetation that is planted or cultivated with the intent to harvest is included in this class (e.g. wheat fields, orchards, rubber and teak plantations). Afforestation is not considered in this class because although it is planted there is no regular modification of the cover.

D.5.2 Urban Park

An urban park is an open (usually green) space within an urban area (city, town, etc.) which provides residents and visitors an area to undertake recreational activities. Playgrounds, paths, sports fields and picnic areas are all examples of facilities provided to visitors.

D.5.3 Plantation

Plantation is usually a large farm or estate mainly planted with trees and shrubs but can include the production of other agricultural products. This quality can be further subdivided into:

— **Forest Plantation**: is for the production of high volume of wood in a short period of time.

— **Orchard** and other plantation: this category includes orchards which are plantation normally devoted to the production of fruit and nuts and any other types of plantations such as sugar cane.

D.5.4 Crop yield

Crop yield represents the harvested production per unit of harvested area for crop products. In most of the cases yield data are not recorded but obtained by dividing the data stored under production element by those recorded under element: area harvested. Data are recorded in hectogram (100 g) per hectare (HG/HA). The crop yield quality in LCML can be used to indicate the production of a specific layer.

D.5.5 Crop growing parameters

Under *Crop Growing Parameters* it is possible to add the following characteristics to Growth Form layer:

— **Seeding time**: month that crop was sown.

— **Growing length**: length in time from sowing to crop maturity (months).

D.5.6 Plant spreading geometry type

The quality *Plant Spreading Geometry Type* allows the user to specify if the life forms have a:

— Regular: the Growth Forms have an ordered and distinguishable geometry (for example rows trees in an orchard).

— Irregular: the Growth Forms within the strata have no specific regular arrangement.

D.5.7 Water supply period

Through the Water Supply Period quality a distinction can be made between rain fed, post-flooding and irrigated practices being used for a specific layer.

— **Rainfed**: Water supply is completely determined by rainfall.

— **Post-flooding**: After rainwater has flooded the field, the water infiltrated into the soil is used intentionally as a water reserve for crop cultivation. The crop(s) use(s) this water reserve for establishment.

— **Irrigated**: Any of several means of providing an artificial regular supply of water, in addition to rain, to the crop(s). Irrigated can be further subdivided into three main irrigation methods:

  — **Surface irrigation**: Water is supplied to the field(s) to form a water layer that infiltrates slowly into the soil. The field may be wetted completed (borders, basins) or partly (furrows, corrugations). The water layer may be moving during irrigation (flow irrigation) or it may be mainly stagnant (check irrigation).

  — **Sprinkler irrigation**: Water is pumped up from a source into a closed distribution network and then conveyed over the soil surface and crops. The irrigation water is applied by means of rotating sprinklers, perforated pipes, sprayers or spinners that are connected to the network. The distribution networks may be permanent, portable or a combination of the two.

  — **Drip irrigation**: This type of irrigation is also called trickle, dribble or localized irrigation. The water is applied at very low pressure through a network of plastic tubes running along the surface or buried. The network consists of main lines and laterals.[12] The water trickles onto the soil near the plant(s) at a confined spot.

D.5.8 Field size

Field Size category allows the user to specify (in hectares) the average size of individual cultivated fields. However, this does not refer to scale of the farming, because it does not relate to the overall size of the farm holding.

D.5.9 Mechanical erosion control

A number of horticultural techniques can be used to prevent soil erosion in agricultural managed areas. LCML allows the user to select the following control methods:

— **Contour ploughing**: is the practice of ploughing across a slope following its contours. The rows formed prevent water run-off and the formation of streams and gullies.

— **Terracing**: In hilly areas a series of level terraces are built into the hill side, giving a stepped appearance. This prevents soil erosion and rapid surface runoff.

— **Wind break**: Windbreaks are usually made up of one or more rows of trees or shrubs planted, often around the edges of fields on farms, to provide shelter from the wind.

D.5.10 Pest control

Pest control is the regulation or management of a number of species which are defined as pests (such as weeds, insects and herbivores) usually because they are perceived to be detrimental to agricultural production, human health and the environment. A number of *pest control* practices can be undertaken and within LCML and these are divided into two main groups, organic and inorganic.

— **Organic**: this is the use of organic agricultural methods, including biological agents such as natural predators, bacteria, fungi and viruses. It also includes microbial biological insecticides, but there are also examples of fungal control agents.

— **Inorganic**: is of non biological origin and include minerals and synthetic products such as certain pesticides.

D.5.11 Crop fertilization

Crop fertilizers are concentrated sources of plant nutrients that are added to growing media. These can be “straight” fertilizers containing only one of the major nutrients (nitrogen, phosphorous, potassium or magnesium) or “compound” fertilizers which supply two or more nutrients.[1] The two main classes which a user can distinguish in LCML are:

— **Organic**: which implies that the fertilizer is derived from living organisms of fertilizers and includes manure, slurry, worm castings, peat, seaweed and sewage. Manufactured fertilizers such as compost, bloodmeal, bone meal and seaweed extracts are also considered organic.

— **Inorganic**: fertilizers are those derived from non living materials usually made of simple inorganic chemicals or minerals

NOTE Some ambiguity in the usage of the term ‘organic’ exists because some of synthetic fertilizers, such as urea and urea formaldehyde, are fully organic in the sense of organic chemistry. In fact, it would be difficult to chemically distinguish between urea of biological origin and that produced synthetically. On the other hand, some fertilizer materials commonly approved for organic agriculture, such as powdered limestone, mined rock phosphate and Chilean saltpetre, are inorganic in the use of the term by chemistry.

D.5.12 Ploughing

Ploughing is to turn over the upper layer of the soil, bringing fresh nutrients to the surface, while burying weeds and the remains of previous crops, allowing them to break down. It also aerates the soil, and allows it to hold moisture better. In modern use, a ploughed field is typically left to dry out, and is then harrowed before planting.

— **Manual**: ploughing is undertaken using hoes and other hand operated utensils.

— **Manual/animal**: ploughing which is undertaken with the use of animals (such as horses, oxen, donkeys, etc.) to provide the physical power to pull the plough which is guided by a human handler.

— **Mechanical**: ploughing undertaken using mechanized machinery with engines such as tractors.

D.6 Artificial Surfaces and associated areas

D.6.1 Surface aspect

The surface aspect of areas with an artificial or associated cover is described. Two main classes are distinguished: *built-up* areas and *non built-up* areas.

D.6.2 Built up surface

Built-up areas are characterized by the substitution of the original (semi-)natural cover or water surface with an artificial, often impervious, cover. This artificial cover is usually characterized by a long cover duration. This metaclass can be sub-divided into *linear* and *nonlinear* surfaces. This category is typified by natural or artificial materials continuously covering the surface, or the soil surface is modified to such an extent that it can no longer be considered as land. In many cases, these structures form a network that covers the land surface.

This surface can consist of hard artificial materials, concrete, gravel or hardened soil or a mixture of any of these materials.

D.6.3 Linear

This category contains exclusively any transport, communication or supply system that is built as a linear structure (its length is greater than its width) in order to connect two locations. The perimeters of the structure and the material of the cover can be further defined. Sub-division is made into *roads*, *railways* and *communication and other types*.

D.6.4 Roads

A more or less uniform material forms a linear structure which covers the land surface over long distances (its length is greater than its width).

The following road types can be selected by the user:

— **Single carriage way**: this is the most common type of road. There is no physical barrier between opposing flows of traffic but the traffic lanes are marked on the road with paint (although small minor and rural roads may not have any markings). A one-way street is, by definition, also a single-carriageway. A road with no central reservation is a single carriageway regardless of the number of lanes of traffic in each direction.

— **Dual carriageway**: is any road with a physical barrier which separates the two flows of traffic. These roads normally have more than one lane of traffic in each direction (motorways also fall under this category).

— **Unpaved**: road which is mainly consists of dirt and gravel. i.e. it does not have asphalt, tar and chip, cobles, concrete, stone or other surface.

D.6.5 Railways

The land cover consists of a combination of materials (e.g. wood, gravel, concrete, iron) with different permeability to form a very specific linear structure.

The user can specify the type of railway track from *high speed rail*, *rapid transit way* and *light rail*.

— **High speed rail**: High-speed is usually defined as a rail line which can support train speeds over 200 km/h For this to be possible the track needs to have a high turn radii, and be welded together, and extremely well supported and anchored to avoid vibrations and other damage. In nearly all high-speed rail is electrically driven via overhead cables and the track is usually un-interrupted, with roads and other tracks crossing over bridges.

— **Rapid transit way**: is an underground, subway, elevated or metro(politan) railway system usually in an urban area, used to transport people. Many cities have such a system (e.g. London Underground). The system is electric powered, independent of other traffic, is a high capacity and is a frequent service.

— **Light rail**: An electric railway with a ‘light volume’ traffic capacity compared to heavy rail. Light rail may use shared or exclusive rights-of-way, high or low platform loading and multi-car trains or single cars.

D.6.6 Communication and other types

This category includes all forms of *pipe lines* (water, sewage, oil, etc.) and *electric lines*. The land cover is characterized by a combination of point-like elements, such as masts, poles, etc. and linear elements such as electric wires and pipes are situated above ground, supported by point-like elements. Examples are telephone wires and electric power transmission lines.

— **Pipe lines**: pine lines are used for the transportation of goods or wastes mainly in the form of liquids or gases (for example: sewage, water, oil and natural gas).

— **Electric lines**: are overhead power transmission lines and power cables which supply the electricity to the consumers from the power plants. Underground power transmission is normally only used in densely populated areas because of the high installation and maintenance costs and also due to large power losses.

D.6.7 Nonlinear surface

This category describes built-up areas where nonlinear artificial constructions cover the land with an impervious surface. The constructed materials may be made up of either of "*Hard Materials*" or "*Light Materials*". A percentage of cover over the ground occupied by the construction can be specified by the user.

— **Hard material**: are structures made out of cement, iron or other hard types of construction materials.

— **Light material**: light wood, plastic and other light materials used to build light constructions such as greenhouses and light wooden prefabricated buildings.

D.6.8 Non-built up DumpSite

This class is defined by absence of the original (semi-) natural cover or water surface and have dump site material placed on its surface. The user can specify between "*Deposit*" and "*Extraction*".

— **Deposits**: is an area covered by materials coming from an outside source (transported by humans). In the system the user can specify from the following two types of deposits:

— **Waste dump**: area, in which the existing land or land cover is covered by waste materials coming from an outside source (transported by humans).

— **Other types of deposit**: is an area covered by materials coming from an outside source (transported by humans). For example, it could be an open storage site for goods, vehicles or other product.

— **Extraction**: extraction site is an area characterized by absence of the original (semi-) natural cover or water surface in which, soil, rock or earthy materials are removed by human activity or machinery. Mining techniques can be divided into two basic groups based on excavation techniques: *surface* and *subsurface*

— **Surface mining**: Surface mining is a type of mining in which soil and rock overlying the mineral deposit are removed. It is the opposite of **underground mining**, in which the overlying rock is left in place, and the mineral removed through shafts or tunnels. Types of mining include: Strip mining, Open-pit mining, Mountaintop removal, Dredging, Highwall Mining.

— **Subsurface**: Underground mining refers to various underground mining techniques used to excavate different types of minerals, hard (such as those containing metals like gold, copper, zinc, nickel and lead or gems such as diamonds) and soft rock (such as coal, or oil sands).

D.7 Abiotic Natural Surface

D.7.1 Abiotic Natural Surface general

The land surface aspect describes the land itself rather than its (semi-)natural or artificial cover. It is sub-divided into two sub elements: Consolidated and Unconsolidated surfaces.

D.7.2 Bare rock

The rock surface is continuous except perhaps for a few cracks in the material. Some areas may be covered by shallow layers of soil or there could be isolated pockets of soil or a mixture of both.

D.7.3 Hardpans

Hardpans are particular soil layers or surfaces that have been indurated due to chemical or physical processes. Their hardness at the surface is irreversible. They form impenetrable layers for water and/or plant roots. In the context of LCML, these layers are only described when occurring at the surface.

D.7.4 Ironpan/Laterite

Soils rich in iron are irreversibly hardened. Iron is the "cement" and the soil contains little or no organic matter.

D.7.5 Petrocalcic

The surface of the soil is cemented or indurated by calcium carbonate to the extent that dry fragments do not slake in water and plant roots cannot penetrate.

D.7.6 Petrogypsic

The surface of the soil is cemented or indurated by gypsum to the extent that dry fragments do not slake in water and plant roots cannot penetrate.

D.7.7 Bare soil

The unconsolidated mineral or organic material on the immediate surface of the earth. In the LCML model this category includes all the unconsolidated material excluding material composed by particles of a certain size typical of the component coarse fragment and loose and shifting sand.

D.7.8 Loose and shifting sand

Unconsolidated material composed by particles between 0,05 mm and 2 mm in diameter. These particles may be moved by regularly occurring winds and forms distinct patterns (see dunes).

D.7.9 Coarse fragments

Coarse Fragments are subdivided in gravel, stones and boulders according to their average size. A percentage of cover of the elements over the soil or rock substratum can be optionally expressed.

D.7.10 Gravel, stones and boulders

The different types of coarse fragments are defined as follows:[32]

— **Gravel** is defined as coarse fragments having a size less than 6 cm.

— **Stones** are defined as coarse fragments having a size between 6 and 20 cm.

— **Boulders** are defined as coarse fragments having a size between 20 and 200 cm.

D.7.11 Deposits

The result of a geological process by which material material organic or inorganic may be added to a landform, that is generally a depression. Deposition can also refer to the buildup of sediments from organically derived matter or chemical or mechanical process.

D.7.12 Peat

Organic soil composed of incomplete decayed organic material. The frequency of peatland is greatest in regions with very humid climate, where the precipitation is much higher than the evaporation. Mire vegetation is adapted to the harsh conditions, for example with low content of oxygen in water and often rather acid soil. When the peat is drained the oxygen supply increases and the peat decaying could increase as well.

D.7.13 Minerotrophic

Peat produced in contact with ground water, beyond or in capillary contact with the water table, is minerotrophic and that type of mire is often called **fen** (transition mire). Minerotrophic peat could develop on overgrowing lakes or poorly drained terrestrial areas.

D.7.14 Ombrotrophic

Peat, connected with a kind of mire called **bog**, is created when there is an excessive precipitation and the contact with the water table is absent. Ombrotrophic peat could develop on top of minerotrophic peat, when the

peat layer has grown thick enough to loose contact with the water table. It could also develop directly on the ground in extremely humid areas, such as the Atlantic areas in Ireland and Norway.

D.8 Macropattern

D.8.1 Macropattern general

The Macropattern describes the horizontal pattern/arrangement of a specific surface aspect of soil or sand. This pattern is formed by the elements that form the bare surface (e.g. sand-sand, soil-soil). Therefore, a distinction is made between *Macropattern – Sand* and *Macropattern – Soil*.

D.8.2 Macropattern sand

LCML allows the user to select from three major categories: "*Dune*", "*Beach*" and "*Salt Flat*".

— **Dune**: Dunes are defined as low ridges or hillocks of drifted sand mainly moved by wind. They occur in deserts or along coasts. The formation of the dunes is dependent on the load of sand, strength and direction of wind, nature of the surface on which sand is moved (sand or rock), presence of an obstacle and the presence of groundwater. Therefore, three types of dunes are distinguished:

  — **Barchans**: Crescent-shaped sand dunes, lying transversely to the wind direction with the 'horns' trailed downwind.

  — **Parabolic**: Elongated dunes with 'horns' pointing upwind.

  — **Longitudinal**: Long, narrow, symmetrical dunes running parallel with the prevailing wind direction.

— **Beach**: Sediments that accumulate along the sea or lake shore.

— **Salt Flats**: Flat area lying just above the water table covered entirely or partially by a layer of salt. Salt flats include shallow salt evaporation ponds (normally on the coastline) and natural salt flats found in deserts and other dry regions (inland) which is ground covered by salt even over a meter thick.

D.8.3 Macropattern soil

LCML allows the user to select from two major categories: "*Termite mounds*" and "*Gilgai*"

— **Termite mounds**: Cone-shaped hills of hardened earth up to several metres high built by termite insects. The termite mounds may be built around tree trunks or poles.

— **Gilgai**: This is the micro-relief typical of Vertisols, which expand and contract largely with distinct seasonal changes in moisture content. Gilgai consists of a 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.[36]

D.9 Water Body and associated surface

D.9.1 Water Body and associated surface general

Depending on the physical status of water a distinction is made into Water, Snow or Ice. Furthermore, it can be specified whether the water or ice is moving or not: Flowing or Standing Water, and Moving or Standing Ice. In addition the system allows the user to specify daily and annual variations.

D.9.2 Water

This category allows the user to classify all types of water phenomena, including rivers, streams, lakes, ponds, canals and other types of water courses. Groundwater is also included in this category. The user can also specify:

— **Water Body dynamics**: the user can specify if the water is "flowing" (such as for rivers and streams) or "standing" (such as ponds, reservoirs and lakes).

— **Water Body positions**: the user can specify is the water body is “above surface” (such as lakes) or “below surface” (such as for ground water).

D.9.3 Snow

Snow are small ice particles of water and it therefore a granular material which can cover land surfaces if the temperatures remain below 0 °C. If required the user can select the following types of snow that have been deposited on the surface:

— **Powder**: uncompacted, low density, low moisture snow (normally freshly fallen).

— **Crud**: is 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 may be powder snow.

— **Slush**: Partially melted snow which forms icy consistency with liquid water forming into pools.

D.9.4 Ice

Water forms into ice when it is cooled below 0 Degrees Celsius forming transparent or opaque solid. The user can specify if the ice is “moving” or “standing”. The user select if the ice is “Terrestrial” or “Floating”.

— **Terrestrial ice** can be classified into the following types:

  — **Permafrost**: refers to earth materials that remain at or below 0 Degrees Celsius for at least two consecutive years.

  — **Ice caps**: although not specifically associated with a specific geographic feature, the domes of ice caps are normally centred around the highest point or mountain peaks, with ice flowing away from the highest point.

  — **Ice fields**: are extensive areas of interconnected valley glaciers but are smaller than ice sheets.

  — **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.

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

  — **Tidewater glacier**: are glaciers that flow into the sea, pieces may break off and form icebergs.

— **Floating ice**. The user may specify if the ice is “Lake Ice”, “River Ice” or “Sea Ice”. For “Sea Ice” the user can further specify if it is:

  — **fast ice**: is sea ice that has frozen along coast or the sea floor and extends out from land into sea.

  — **drift ice**: sea ice that floats on the surface.

D.9.5 Water nutrient level

The level of nutrients in a water body:

— **Oligotrophic**: A water body which is oligotrophic has low content of nutrients, such as phosphorus. The primary productivity is low, content of oxygen is high and the water is in most cases very clear.

— **Mesotrophic**: A water bodies which is mesotrophic has intermediate content of nutrients, such as phosphorus. The primary productivity and oxygen content is intermediate.

— **Eutrophic**: A water bodies which is eutrophic has a high content of nutrients, such as phosphorus. Due to the high primary productivity the oxygen content could sink to low levels. The water has poor visibility.

D.10 Artificial Surface characteristics

D.10.1 Construction status

This category defines the status of any type of built up surface. It is divided in:

— **Finished**: construction has been completed and is being used for the specified purpose specified.

— **In progress**: construction has begun but is still to be completed.

— **Abandoned**: the construction is no longer being used for the purpose intended or was never completed.

D.10.2 Construction use

This category defines the use of any type of built up surface. The users are free to define their own list.

D.11 Water and associated surface characteristics

D.11.1 Salinity

Water salinity is described according to the concentration of Total Dissolved Solids (TDS), expressed in parts per million (ppm), giving the following classification:

— **Fresh**: less than 1 000 ppm TDS.

— **Brackish**: 1 000 – 3 000 TDS.

— **Saline**: 3 000 – 35 000 TDS.

— **Brine**: more than 35 000 ppm TDS (= water saturated or nearly so with salt).

D.11.2 Artificiality

The user can state if the water body, such as a lake or reservoir, was formed through natural processes or was constructed by human intervention (e.g. dams to create lakes etc.):

— **natural**: formed by natural phenomena, such as erosion, plate movements, etc.

— **artificial**: formed through human intervention, such as dams, embankments, etc.

D.12 Land Cover class characteristics

D.12.1 Climate

The Intergovernmental Panel on Climate Change (IPCC) glossary definition of climate change is:[5] Climate in a narrow sense is usually defined as the “average weather”, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The different types of climate are user defined.

D.12.2 Topographical aspects

The user can provide some general description of the topographical aspects of the land surface including:

— **Altitude**: Altitude is the vertical elevation above mean sea level in metres.

— **Slope**: is used to describe the steepness, incline, gradient and is calculated by dividing the change in height by the distance it takes for the change in slope to occur. The user can also specify the “Slope Exposition”: “North”, “South”, “East” and “West”.

D.12.3 Surface characteristics

The user can specify a number of surface characteristics of the land which are divided into *Consolidated Surface Characteristics* and *Unconsolidated Surface Characteristics*.

— **Consolidated Surface characteristics**: This allows users to specify *rock type* and *rock age*.

— **Unconsolidated Surface characteristics**: This allows users to describe *soil type* and different forms of *erosion*.

  — **Soil types**: the different soil types are used defined.

  — **Erosion type**: Erosion is the process of the removal of solids (such as soil, rock, sediment and other materials) by a number of possible agents such as, wind, water, ice, gravity and living organisms.

    — **Water erosion sheet**: Sheet erosion is the process were rain drops splash on the ground causing soil particles to be knocked into the air. The loose particles then move down slope by broad sheets of rapidly flowing water.

    — **Water erosion rill**: A rill is a narrow and shallow incision into soil resulting from erosion by water runoff.

    — **Water erosion gully**: Gullies are formed by running water which erodes sharply into the soil. It occurs typically on hill sides and they can resemble large ditches or small valleys and be many metres deep and long.

    — **Wind erosion**: Wind can cause erosion by lifting and removing particles and in addition suspended particles may collide with other objects causing further erosion.

    — **Ice erosion**: The movement of ice, such as glaciers, causes erosion by scrapping the basal rock (abrasion/scouring) and by breaking of whole pieces of the basal rock (plucking).

    — **Gravity erosion**: is the movement of rock and sediment down a slope due to the force of gravity (this process includes mass movement, landslides and slumping (release of a large block of material down the slope).

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